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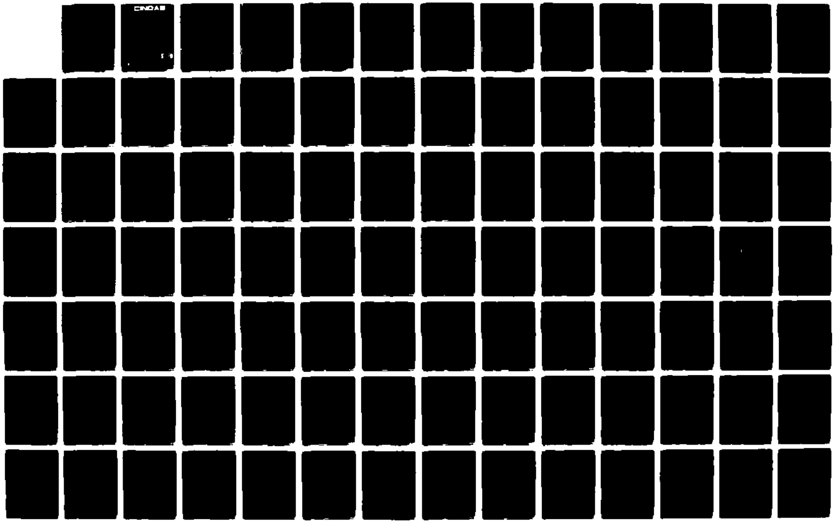

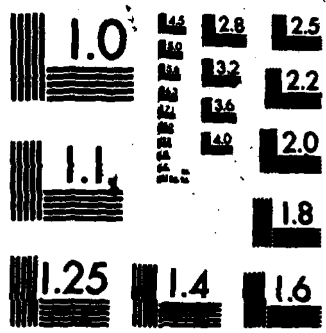

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THERMAL CONDUCTIVITY OF TEN SELECTED BINARY ALLOY SYSTEMS

By

C. Y. Ho, M. W. Ackerman, K. Y. Wu, S. G. Oh, and T. N. Havill

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This work presents and discusses the available data and information on the thermal conductivity of ten selected binary alloy systems and contains the recommended reference values (or provisional or typical values) resulting from critical evaluation, analysis, and synthesis of the available data and information. The ten binary alloy systems are the systems of aluminum-copper, aluminum-magnesium, copper-gold, copper-nickel, copper-palladium, copper-zinc, gold-palladium, gold-silver, iron-nickel, and silver-palladium. The recommended (or provisional or typical) values given include the total thermal

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PREFACE

This technical report was prepared by the Thermophysical Properties Research Center (TPRC) of the Center for Information and Numerical Data Analysis and Synthesis (CINDAS), Purdue University, West Lafayette, Indiana, under the auspices of the Office of Standard Reference Data of the National Bureau of Standards (NBS), Department of Commerce, Washington, D.C. It represents the most exhaustive review and critical evaluation of the recorded world knowledge on the thermal conductivity of ten selected binary alloy systems, and is a continuation of a similar work on the thermal conductivity of the elements already published. The recommended self-consistent thermal conductivity values presented in this report cover the full ranges of composition and temperature for most of the alloy systems and go far beyond the limited experimental data, which are often conflicting and uncertain in many cases. Thus, new knowledge has been generated in this process of data analysis and synthesis.

This report serves many purposes. It provides engineering and design data for virtually all compositions of the ten alloy systems for industrial applications. It provides reliable data for those alloys that can be used as reference materials to check apparatus for thermal conductivity measurements or as standards in comparative thermal conductivity measurements. It provides reliable data against which theoreticians can test their theories. Furthermore, the knowledge of the thermal conductivity of binary alloy systems is essential for the study and estimation of the thermal conductivity of ternary and more complex engineering alloys. A reliable method for the calculation of the thermal conductivity of binary alloys has also been developed in this work, which will have wide applications.

Although this report is primarily the result of financial support and interest of the NBS Office of Standard Reference Data, the extensive documentary activity essential to this work was supported by the Defense Supply Agency of the Department of Defense. Throughout the course of this work, Dr. P. G. Klemens, who is a Visiting Research Professor at CINDAS and Professor of Physics at the University of Connecticut, has given the staff of this project invaluable technical guidance and advice; his contributions are hereby gratefully acknowledged. Thanks are also due Dr. H. J. White, Jr., of the NBS Office of Standard Reference Data for his sympathetic understanding and help in many ways and to Dr. D. L. McElroy of the Oak Ridge National Laboratory for useful comments and discussions.

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ABSTRACT

This work presents and discusses the available data and information on the thermal conductivity of ten selected binary alloy systems and contains the recommended reference values (or provisional or typical values) resulting from critical evaluation, analysis, and synthesis of the available data and information. The ten binary alloy systems are the systems of aluminum-copper, aluminum-magnesium, copper-gold, copper-nickel, copper-palladium, copper-zinc, gold-palladium, gold-silver, iron-nickel, and silver-palladium. The recommended (or provisional or typical) values given include the total thermal conductivity, electronic thermal conductivity, and lattice thermal conductivity. The values for each of the alloy systems except two are given for 25 alloy compositions: 0.5, 1, 3, 5, 10(5)95, 97, 99, and 99.5%. For most of the alloy compositions, the values cover the temperature range from cryogenic temperature to the solidus point or 1200 K. In addition, reliable methods for the estimation of the electronic and lattice thermal conductivities of alloys have been developed in this work.

Key words: Alloys; conductivity; critical eavluation, data analysis; data compilation; data synthesis; electrical resistivity; metals; reference data; thermal conductivity; thermoelectric power.

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NOMENCLATURE

a	Lattice constant
e	Electronic charge; Base of natural logarithm (2.71828)
E	Electron energy
$E_{\vec{k}}$	Energy of electron in $\vec{k}$th state
$f(\vec{k})$	Distribution function representing the number of carriers in $\vec{k}$th state
f^0	Fermi-Dirac distribution function at equilibrium
$\hbar$	Reduced Planck constant
I_a, I_b, I_c	Transport integrals
I_n	Modified transport integrals
J_n	Standard transport integrals
k	Total thermal conductivity
k_e	Electronic thermal conductivity
k_{ei}	Intrinsic electronic thermal conductivity
k_g	Lattice thermal conductivity
k_u	Lattice thermal conductivity of a virtual crystal
$\vec{k}$	Electron wave vector
K	Kelvin temperature unit
K_n	Electronic transport integrals
L	Lorenz function
L_0	Lorenz number (2.443×10^{-8} V^2 K^{-2})
M	Average atomic mass
M_H	Atomic mass of the heavier element
M_L	Atomic mass of the lighter element
n	Number of conduction electrons per atom
S	Absolute thermoelectric power
T	Temperature
v	Speed of sound
$v(E)$	Electron velocity in spherical symmetry

$v(\vec{k})$	Velocity of electron in $\vec{k}$th state
V	Average atomic volume
V_H	Atomic volume of the heavier element
V_L	Atomic volume of the lighter element
W_e	Electronic thermal resistivity
W_{ei}	Intrinsic electronic thermal resistivity
W_{e0}	Residual electronic thermal resistivity
W_{Hi}	Contribution to W_{ei} of electrons moving parallel to the Fermi surface
W_{Vi}	Contribution to W_{ei} of electrons moving perpendicular to the Fermi surface
ΔW	Deviation from thermal analog of Matthiessen's rule
x	Reduced phonon frequency
x_0	Reduced phonon frequency at which the relaxation times for point-defect scattering and U-processes are equal
y	Atomic fraction of the solute
y_H	Atomic fraction of the heavier element
y_L	Atomic fraction of the lighter element
α	Ratio of reciprocal relaxation times for N- and U-processes
β	Impurity-imperfection parameter of elements
γ	Grüneisen parameter
ϵ	Quantity characterizing the perturbation due to mass defects and lattice distortion
ζ	Fermi energy
η	Reduced electron energy
θ	Debye temperature
κ	Boltzmann constant
μ	Ferromagnetic ordering parameter
ρ	Total electrical resistivity
ρ^*	Resistivity of ferromagnetic metal in the absence of ferromagnetic ordering
ρ_0	Residual electrical resistivity
ρ_i	Intrinsic electrical resistivity

$\Delta\rho$	Deviation of electrical resistivity from Matthiessen's rule
$\tau(\vec{k})$	Relaxation time for electron in $\vec{k}$th state
$\tau(E)$	Relaxation time for electron with energy E in spherical symmetry
τ_c	Combined relaxation time
τ_N	Relaxation time for N-processes
τ_p	Relaxation time for point-defect scattering
τ_U	Relaxation time for U-processes
ω	Frequency of lattice wave
ω_o	Phonon frequency at which the relaxation times for point-defect scattering and U-processes are equal

1. INTRODUCTION

The primary objective of this study was to critically evaluate, analyze, and synthesize all the available data and information on the thermal conductivity of ten selected binary alloy systems and to generate recommended reference data over the widest practicable ranges of temperature and alloy composition for each of the alloy systems. It will become evident that for most of these alloy systems there are serious gaps in the thermal conductivity data, as concerns dependence on composition or temperature, or both, and that most of the available data show large uncertainties or wide divergences. It has, therefore, been necessary to set other objectives: (1) to develop reliable methods for the estimation of the thermal conductivity of alloys, (2) to determine the extent to which the methods of data estimation developed in this study are applicable in general, and (3) to identify those areas where further theoretical and experimental research is needed.

The ten alloy systems selected for this study are the systems with the largest amount of experimental data among some 200 alloy systems for which thermal conductivity data are available. This selection of alloy systems with the largest amount of experimental data is necessary since data evaluation is possible only when data are available and the availability of fairly sufficient data for an alloy system is prerequisite for detailed data analysis, correlation, and synthesis.

The systems selected represent all three different kinds of binary alloy systems: nontransition-metal and nontransition-metal systems (aluminum-copper, aluminum-magnesium, copper-gold, copper-zinc, and gold-silver), nontransition-metal and transition-metal systems (copper-nickel, copper-palladium, gold-palladium, and silver-palladium), and a transition-metal and transition-metal system (iron-nickel). The inclusion of this wide range of alloy systems in this study has tested the broad applicability of the methods developed for data estimation and synthesis.

The methods developed for the estimation of the thermal conductivity of alloys are detailed in Section 2. These methods have been extensively tested with key sets of reliable experimental data. In Section 3 the procedures for data evaluation and for the generation of recommended values are outlined, including the procedures for data estimation using the methods detailed in Section 2.

The recommended (or provisional) values for the total thermal conductivity, electronic thermal conductivity, and lattice thermal conductivity and the original experimental data for the thermal conductivity of the ten selected binary alloy systems are reported in Section 4, together with a discussion of each system, reviewing individual pieces of available data and information, giving details of data analysis and synthesis, and discussing the considerations involved in arriving at the final assessment and recommendations. For each

of the alloy systems except two (aluminum-magnesium and copper-zinc), the recommended (or provisional) thermal conductivity values are given for 25 alloy compositions: 0.5, 1, 3, 5, 10(5)95, 97, 99, and 99.5%, which greatly facilitates the interpolation of values for alloys with intermediate compositions. These values are for well-annealed disordered alloys.

The complete bibliographic citations for the 184 references are given in Section 6.

2. THEORETICAL BACKGROUND

In metals and alloys the principal carriers of thermal energy are electrons and lattice waves, and it is commonly assumed that the total thermal conductivity is

$$k = k_e + k_g \tag{1}$$

where k_e is the electronic thermal conductivity and k_g is the lattice thermal conductivity; these are the thermal conductivity components due to the transport of heat by the electrons and by the lattice waves or phonons, respectively.

In pure normal metals, conduction by lattice waves is negligible in comparison with conduction by electrons at all temperatures, but in alloys the lattice component is often comparable to and sometimes even greater than the electronic component at low temperatures and is not negligible even at temperatures well above the Debye temperature in some cases. Hence, in order to estimate the thermal conductivity of an alloy it is necessary to estimate both the electronic and lattice components. Since the principal thermal resistance mechanisms differ in different temperature regions, it is necessary to devise different methods for making predictive estimates in different temperature regions. In the course of developing these methods a number of specific areas in which further experimental and theoretical studies are needed were identified.

2.1. Electronic Thermal Conductivity

In alloys at temperatures below about 25 K the only significant contribution to the electronic thermal resistivity, W_e, is the scattering of electrons by solute atoms, so that the electronic thermal conductivity may be calculated from the Wiedemann-Franz-Lorenz relationship,

$$k_e = \frac{1}{W_e} \approx \frac{1}{W_{e0}} = \frac{L_0 T}{\rho_0} \tag{2}$$

where W_{e0} is the residual electronic thermal resistivity due to impurity scattering of electrons, ρ_0 is the residual electrical resistivity, T is the temperature, and L_0 is the classical theoretical Lorenz number and has a value of $2.443 \times 10^{-8}\ V^2\ K^{-2}$.

At higher temperatures the scattering of electrons by lattice waves becomes significant. At temperatures between about 25 K and 100 K the electronic thermal resistivity has commonly been estimated from the thermal analog of Matthiessen's rule,

$$W_e = W_{e0} + W_{ei} = \rho_0/L_0 T + W_{ei} \tag{3}$$

where W_{ei} is the intrinsic electronic thermal resistivity, which is the reciprocal of the intrinsic electronic thermal conductivity, k_{ei}, of the "parent" element, and Matthiessen's

rule states that the electrical resistivity is composed of a residual and an intrinsic component:

$$\rho = \rho_0 + \rho_i \tag{4}$$

Equation (3) is based on the assumption that the deviations from Matthiessen's rule, $\Delta\rho = \rho - \rho_0 - \rho_i$, and its thermal analog, $\Delta W = W_e - W_{e0} - W_{ei}$, can be neglected. This is not the case at higher temperatures; $\Delta\rho$ and ΔW may be significant even at temperatures below 100 K. These deviations may be taken into account by assuming that they are related by the Wiedemann-Franz-Lorenz law: $\Delta\rho/\Delta W = LT$, where L is the Lorenz ratio which may or may not be equal to L_0. This assumption is based on an argument by Klemens [1]* which may be summarized as follows.

The intrinsic electrical and thermal resistivities arise from interactions between electrons and phonons which take electrons from regions of momentum space where there are too many into regions where there are too few electrons relative to the equilibrium concentration. Since the phonon energies are relatively small, the electron energies are little changed by these interactions, and their initial and final states must both lie near the Fermi surface.

In the case of electrical conduction the deviation of the distribution function from the equilibrium distribution due to the electric field is proportional [2] to a function, $f(\vec{k})$, of the direction of the electron wave vector, the sign of the deviation depending on the direction of the electron wave vector. The intrinsic electrical resistivity, ρ_i, is the result of the motion of electrons in $\vec{k}$ space through interactions with phonons to distant regions of the Fermi surface, involving substantial changes in the direction of $\vec{k}$, which is a "horizontal" movement on the Fermi surface.

In the case of thermal conduction, the deviation from the electronic equilibrium distribution due to the temperature gradient is proportional to the same function $f(\vec{k})$ of the direction of the electron wave vector but it is also proportional to the reduced electron energy, $\eta = (E-\zeta)/\kappa T$, E being the electron energy, ζ the Fermi energy, and κ the Boltzmann constant. Thus the sign of the deviation of the distribution function can be changed not only by "horizontal" movement on the Fermi surface but also by changing the sign of η, which is a "vertical" movement through the Fermi surface. These motions in $\vec{k}$ space contribute approximately additively to the intrinsic electronic thermal resistivity: $W_{ei} \approx W_{Hi} + W_{Vi}$. Since $f(\vec{k})$ is the same for electrical and thermal conduction, horizontal movement is equally effective in both cases, so that ρ_i and W_{Hi} are related by the Wiedemann-Franz-Lorenz law. Now W_{Vi} depends on a local property of the Fermi surface and is, therefore, relatively insensitive to changes in the band structure due to alloying. On the other hand W_{Hi},

* Numbers in brackets designate references listed in Section 6.

being due to motion of the electrons over large distances on the Fermi surface, is sensitive to changes in its overall shape, particularly when these changes involve contact with the zone boundary which effectively short circuits the horizontal movement. Hence the change in W_{Hi} on alloying is much larger than the change in W_{Vi} and makes the dominant contribution to the deviations from Matthiessen's rule. Thus, to a good approximation, the deviations from Matthiessen's rule and its thermal analog are related by the Wiedemann-Franz-Lorenz law,

$$W_e = (\rho - \rho_i)/LT + W_{ei} \tag{5}$$

or

$$k_e = \frac{1}{(\rho - \rho_i)/LT + W_{ei}} \tag{6}$$

In applying eq. (6), W_{ei} and ρ_i are taken to be the intrinsic thermal and electrical resistivities of the virtual crystal obtained by interpolating between the values for the elements, linearly for alloys of ordinary metals and according to Mott's theory [3, 4] for alloys containing transition elements. For most alloys W_{ei} is much smaller than the other term in eq. (6) so that the error introduced in common practice by taking W_{ei} of the elements to be the reciprocals of their total thermal conductivities is also small. However, in dilute alloys of elements which do not have electronic thermal conductivities comparable to those of the noble elements this error is significant, and W_{ei} is therefore calculated in this work from the expression

$$W_{ei} = \frac{1}{k_{ei}} = \frac{1}{k_e} - \frac{\beta}{T} = \frac{1}{k - k_g} - \frac{\beta}{T} \tag{7}$$

where β is the impurity-imperfection parameter of the element. The values of k and β of the elements are available from ref. [5]* and the values of k_g of an element at moderate and high temperatures are calculated from eq. (36). The values of electrical resistivities of the ten selected binary alloy systems and their nine constituent elements used in eq. (6) are available from ref. [7].

From the argument leading to eq. (6) it is clear that the value of L used therein should be that for horizontal motion on the Fermi surface, or for elastic scattering; the values of L appropriate for use in eq. (6) and in the Wiedemann-Franz-Lorenz law, which one might expect to be valid at high temperatures where phonons scatter electrons through large angles, are discussed below.

It should be noted that eq. (6) may not be valid in some cases. If the deviations from Matthiessen's rule are due to the fact that two bands of electrons, such as those on

* The recommended values for the thermal conductivities of the elements given in ref. [5] in some cases are slightly different from those given in ref. [6], and the values given in ref. [5] are preferred and should be used whenever there is a difference.

the neck and belly regions of the Fermi surface, contribute significantly to the electrical conduction, then, in general, the deviations from Matthiessen's rule and its thermal analog are not related by the Wiedemann-Franz-Lorenz law.

Significant deviations of the Lorenz ratio from its classical value can result from band structure effects and from electron-electron scattering.

The possibility of deviations due to band structure effects and the difficulties they present may be seen from the following. Assuming the existence of a relaxation time, the electronic transport properties can be expressed through integrals over reciprocal space of the form

$$K_n = -\frac{1}{3}\iiint v^2(\vec{k})\ \tau(\vec{k})\ (E_{\vec{k}} - \zeta)^n \frac{\partial f^0}{\partial E_{\vec{k}}}\, d^3\vec{k} \tag{8}$$

which for spherical symmetry [182] reduces to

$$K_n = \frac{1}{12\pi^3\hbar}\iint_{-\infty}^{\infty} v(E)\ \tau(E)\ (E-\zeta)^n \frac{\partial f^0}{\partial E}\, dA\, dE \tag{9}$$

Here $\hbar$ is the reduced Planck constant, v is the electron velocity, τ is the relaxation time, E is the electron energy, f^0 is the Fermi-Dirac distribution function, ζ is the Fermi energy, and dA is an element of a constant energy surface in reciprocal space. In particular, the absolute thermoelectric power is given by

$$S = \frac{1}{eT}\frac{K_1}{K_0} \tag{10}$$

and the Lorenz ratio by

$$L = \frac{1}{e^2T^2}\left[\frac{K_2}{K_0} - \frac{K_1^2}{K_0^2}\right] = \frac{1}{e^2T^2}\frac{K_2}{K_0} - S^2 \tag{11}$$

Because of the factor $\partial f^0/\partial E$, the only significant contributions to these integrals are from energies differing from ζ by no more than κT, where κ is the Boltzmann constant, so that the usual procedure is to expand each integrand in a Taylor series about ζ. Retaining only the leading term of the series leads to the result $L = L_0 - S^2$, where L_0 is the classical theoretical Lorenz number. The values of L obtained from this result are used in eq. (6) to give the equation employed in our calculations:

$$k_e = \frac{1}{\dfrac{\rho-\rho_i}{(L_0-S^2)\,T} + W_{ei}} \tag{12}$$

The values of absolute thermoelectric powers of the ten selected binary alloy systems used in eq. (12) are available from ref. [40].

There is some question about the choice of L_0 in the case of transition-element alloys. The difficulties occur also in the treatment of the pure transition metals, and will be reviewed briefly in that context.

If, as in the case of some transition metals, a narrow band with a high density of states overlaps the conduction band at the Fermi energy, then at high temperatures it is necessary to include higher order terms in the series and this will cause a deviation of the Lorenz ratio from the classical value. It is possible, at least in principle, to evaluate the second order terms from the thermoelectric power and the series expansion for the electrical conductivity (see Williams and Fulkerson, 1969 [8, pp. 443-7]). However, if the relaxation time is a strong function of energy, as is the case in transition metals on the assumption [9] that it may be written as the reciprocal of the product of the density of states and a scattering probability per unit time, then a Taylor series expansion about ζ may not be adequate to represent the integrand over the energy range κT at high temperatures. In such cases the integrals must be evaluated numerically. This has been done for Pd [10] and reasonable agreement between theory and experiment was obtained; the discrepancies were presumably due to electron-electron scattering [11, p. 412] which occurs in both ordinary and transition metals. In ordinary metals, *normal electron-electron scattering*, in which electron quasi-momentum is conserved, contributes to the thermal resistivity but not to the electrical resistivity and thus causes a negative deviation of the Lorenz ratio. Such a deviation has been observed in Cu [12, 13]. In transition metals normal electron-electron interactions between s and d band electrons contribute to the electrical resistivity as well as to the thermal resistivity; these processes are very strong [14, 15] and are generally thought to be responsible for the T^2 temperature dependence of the electrical resistivity observed in these metals at low temperatures. The deviation of the Lorenz ratio due to electron-electron scattering may either enhance or partially cancel the effects of band structure. The latter appears to be the case in the group VIII elements [16]. The deviations of the Lorenz ratio of transition metals due to band structure effects are significant and cannot yet be calculated directly; further, in order to calculate correlations between the electrical resistivity and the Lorenz ratio, the density of states function of the material must be known and there are difficulties in including the effects of electron-electron scattering in such an analysis.

The Wiedemann-Franz-Lorenz law is valid in alloys at very low temperatures where one need consider only impurity scattering, and in both metals and alloys at high temperatures where phonons scatter electrons through large angles. Equation (12) was developed in order to calculate the electronic component at intermediate temperatures. However,

as is clear from the preceding discussion, in the case of transition-metal alloys there is considerable uncertainty about the values of the Lorenz ratio to be used in the Wiedemann-Franz-Lorenz law at high temperatures. The method tried was to interpolate for the deviation from the classical value on the basis of the questionable assumption that the net deviation resulting from band structure effects and s-d electron-electron scattering is proportional to the number of holes in the d band. It was found that in the Cu-Ni system the resulting values of k_e nowhere differed from those obtained from eq. (12) by more than 5 percent and it was decided to use eq. (12) over the entire temperature range above 25 K.

In view of the uncertainties associated with eq. (12), it is reassuring that the values obtained from it have been found to be in good agreement with the values of the electronic component obtained from experimental values of thermal conductivity considered to be reliable on the basis of the usual criteria.

While a considerable amount of effort has been concentrated on the study of deviations from Matthiessen's rule, far less attention has been given to their relation to the deviations from its thermal analog [1,17,18]. Work in this area is hindered by the failure of many authors to include the corresponding electrical resistivity data when reporting thermal conductivity values. Further work in this area would help to determine the limitations of eq. (12) and very probably lead to improvements on it.

2.2. Lattice Thermal Conductivity

The processes limiting lattice conduction are different in the temperature regions below, about, and above the temperature at which it has its maximum value. At very low temperatures, typically below one twentieth of the Debye temperature, θ, these are the ordinary and impurity-induced electron-phonon interactions and, in strained specimens, phonon scattering by dislocations. These processes are also important in the temperature range in which the lattice component has its maximum value, typically between $\theta/20$ and $\theta/5$ for alloys of ordinary metals but considerably higher for some transition elements, but in this region point-defect scattering and three-phonon anharmonic interactions also contribute to the thermal resistivity. At temperatures above this region the important resistive processes in alloys of ordinary metals are three-phonon anharmonic interactions and point-defect scattering; in alloys containing transition metals the effect of electron-phonon interactions may also be significant in the lower portion of this temperature range. This third region is the only one in which it is possible to estimate the lattice component on the basis of present theory.

a. Low Temperature Region

The problem of calculating the coupling constant for the electron-phonon interaction is a very difficult one even in the simplest cases; in fact, measurements of low temperature

alloy thermal conductivity were initially undertaken to obtain information about this interaction. From results reported by Lindenfeld and Pennebaker [19] for Cu alloys it appeared that it might be possible to estimate the lattice component from electrical resistivity data on the basis of present theory. This did not prove to be the case. It was found that values obtained from an expression which follows from the equations in ref. [19] differed from those obtained from measurements by as much as a factor of three. It is almost certain that these discrepancies are largely the result of the use of Pippard's early results [20] which are based on the free electron model; this simple model is inadequate for most metals and alloys.

At temperatures below $\theta/20$, the lattice thermal conductivity of a pure ordinary metal may be calculated from an expression derived by Klemens [21]

$$k_g = \frac{313\, k_{ei}\, T^4}{n^{4/3}\, \theta^4} \tag{13}$$

where n is the number of conduction electrons per atom, θ is the Debye temperature, and k_{ei} is the intrinsic electronic thermal conductivity. Since in this region k_{ei} is inversely proportional to T^2, k_g has a T^2 temperature dependence. Equation (13) is based on the assumption of a reciprocal effect of the electron-phonon interaction on electronic and lattice conduction and therefore does not apply to transition elements in which electron-phonon interactions involving only d band electrons have little effect on electrical conductivity but may have a significant effect on lattice conduction. It also does not apply to alloys in which the electron mean free path is so short that the usual treatment of the electron-phonon interaction is invalid; typically, these are alloys in which the residual resistivity is 10 $\mu\Omega$ cm or greater.

However, if one attempts to estimate the k_g of an alloy from this expression the value obtained is greater than the experimental value by a factor which increases rapidly with solute concentration up to approximately 10 atomic percent. A possible explanation of this behavior is that it is due to phonon scattering by dislocations which are so strongly anchored by solute atoms that they remain even after prolonged annealing at high temperatures. The experimental support for this idea is some recent measurements on Cu-Al alloys at the University of Connecticut [22] which show that such behavior is not observed at temperatures below about 0.5 K, where the dominant phonon wavelengths are larger than the range of the dislocation strain fields so that scattering by dislocations is greatly reduced [23].

Consequently, at present one cannot make reliable estimates of the k_g of alloys at low temperatures and it must be obtained by subtracting k_e from the measured total thermal conductivity. Further, one can obtain reliable values of the k_g from thermal conductivity measurements only in those cases in which the corresponding values of electrical resistivity

are given, as there is often a significant variation in the resistivities of specimens having the same nominal composition. It is unfortunate that while there is a sizable body of experimental data showing strong composition dependence of the low-temperature thermal conductivity of alloys, in most cases the corresponding values of the electrical resistivity are not reported, so that it is not possible to relate the changes in the two quantities. Finally, in view of the probability that residual dislocations are responsible for a large portion of the thermal resistivity, one cannot reliably extrapolate curves of the lattice component down to temperatures below about 1.5 K.

In order to make it possible to estimate the lattice component at low temperatures by other than empirical means, it is necessary to develop both a quantitative theory of impurity enhancement of the phonon scattering in alloys of ordinary metals and a theory of low temperature lattice conduction in transition element and high residual resistivity alloys. It seems that progress in these directions will involve the use of Pippard's more general equations [24] which apply to a non-spherical Fermi surface, taking into account changes in its shape with the addition of solutes. However, application of this theory to transition metals presents a difficult problem. Since electrical conduction is mainly by s band electrons, the residual resistivity is a measure of the mean free path of the s electrons and provides no information about the mean free path of the d band holes, which is probably very short.

b. Intermediate Temperatures

At temperatures near the maximum of the lattice component the resistive processes which limit lattice conduction at lower and higher temperatures are comparable in magnitude and the problem of estimating the lattice component in this region is a formidable one. It is, first, because of the difficulties associated with the electron-phonon interaction discussed above and, secondly, because the treatment of the resistive three-phonon anharmonic interaction in this region is complicated by the fact that here the strength of these interactions is a rapidly varying function of temperature.

At present there is no method available for the calculation of k_g in this temperature region. In this work the values of k_g in this region are derived from experimental data and the calculated values of k_e.

c. High Temperature Region

At temperatures above the region of the maximum of the lattice component, typically $\theta/5$ for alloys of ordinary metals but considerably higher for some transition-element alloys, it is possible to estimate the lattice thermal conductivity on the basis of a theory developed by Klemens [25] and Callaway [26] assuming that the effect of the electron-phonon interaction can be neglected; this is not the case for some transition elements in the lower portion of this temperature range.

The reciprocal relaxation time for the thermally resistive three-phonon anharmonic interactions, U-processes, at frequencies not too close to the Debye limit is of the form $BT\omega^2$ where B is a constant determined from experiment, T is the temperature, and ω is the frequency of the lattice wave. The reciprocal relaxation time for point-defect scattering is of the form $(a^3/4\pi v^3)\,\epsilon\,\omega^4$ where a^3 is the average volume per atom, v is the speed of sound, and ϵ is a quantity which characterizes the perturbation due to mass defects and distortions of the lattice. In addition, there are three-phonon anharmonic interactions, N-processes, which do not contribute directly to the thermal resistivity but do contribute indirectly by redistributing energy from the low frequency modes to the high frequency modes which are strongly scattered by the point defects. The reciprocal relaxation time for N-processes has the same form as that for the U-processes and, as argued by Klemens, et al. [27], appears to have approximately the same magnitude in this temperature region.

Since N-processes do not contribute directly to the thermal resistivity, the effective total reciprocal relaxation time is not simply the sum of the individual reciprocal relaxation times. Callaway devised a formalism in which the N-processes are taken into account correctly for steady state lattice conduction.

Callaway found that the lattice thermal conductivity is given by

$$k_g = \frac{\kappa}{2\pi^2 v}\left(\frac{\kappa T}{\hbar}\right)^3\left(I_a + \frac{I_b^2}{I_c}\right) \tag{14}$$

where

$$I_a = \int_0^{\theta/T} \tau_c \frac{x^4 e^x}{(e^x-1)^2}\,dx \tag{15}$$

$$I_b = \int_0^{\theta/T} \frac{\tau_c}{\tau_N} \frac{x^4 e^x}{(e^x-1)^2}\,dx \tag{16}$$

$$I_c = \int_0^{\theta/T} \frac{1}{\tau_N}\left(1 - \frac{\tau_c}{\tau_N}\right) \frac{x^4 e^x}{(e^x-1)^2}\,dx \tag{17}$$

and κ and $\hbar$ are the Boltzmann constant and the reduced Planck constant, v is the speed of sound, and $x = \hbar\omega/\kappa T$ is the reduced phonon frequency. Here τ_c is a combined relaxation time, obtained as the reciprocal of the sum of the reciprocal relaxation times for the various interactions, τ_N is the relaxation time for N-processes, and the term I_b^2/I_c occurs because of the difference between τ_c and the effective total relaxation time resulting from the fact that N-processes do not contribute directly to the thermal resistivity.

Writing the reciprocal relaxation times for point-defect scattering, U-processes and N-processes as $\tau_p^{-1} = A\omega^4$, $\tau_u^{-1} = BT\,\omega^2$, and $\tau_N^{-1} = \alpha BT\,\omega^2$ respectively, where α

is the temperature-independent ratio of reciprocal relaxation times for N- and U-processes, the reciprocal combined relaxation time when the lattice thermal conductivity is limited by these interactions is

$$\tau_c^{-1} = \omega^2 \left[A\omega^2 + BT\ (1+\alpha)\right] \tag{18}$$

so that

$$\frac{\tau_c}{\tau_N} = \frac{\alpha\, BT}{A\omega^2 + BT\ (1+\alpha)} \tag{19}$$

and

$$\frac{1}{\tau_N}\left(1 - \frac{\tau_c}{\tau_N}\right) = \alpha\, BT\omega^2\left(1 - \frac{\alpha\, BT}{A\omega^2 + BT\ (1+\alpha)}\right) = \frac{\alpha\, BT\omega^2\ (A\omega^2 + BT)}{A\omega^2 + BT\ (1+\alpha)} \tag{20}$$

Upon denoting the frequency at which the reciprocal relaxation times for point-defect scattering and U-processes are equal by ω_0, noting that $\omega_0^2 = BT/A$, and introducing the reduced frequency $x = \hbar\,\omega/\kappa T$, so that $x_0 = \hbar\,\omega_0/\kappa T$, these relations become:

$$\tau_c^{-1} = BT\ \omega^2\ (1 + \alpha + \omega^2/\omega_0^2) = BT\left(\frac{\kappa T}{\hbar}\right)^2 x^2\ (1 + \alpha + x^2/x_0^2) \tag{21}$$

$$\frac{\tau_c}{\tau_N} = \frac{\alpha}{1 + \alpha + \omega^2/\omega_0^2} = \frac{\alpha}{1 + \alpha + x^2/x_0^2} \tag{22}$$

and

$$\frac{1}{\tau_N}\left(1 - \frac{\tau_c}{\tau_N}\right) = \frac{\alpha\ BT\ \omega^2\ (1 + \omega^2/\omega_0^2)}{1 + \alpha + \omega^2/\omega_0^2} = \alpha\ BT\left(\frac{\kappa T}{\hbar}\right)^2 x^2\ \frac{(1 + x^2/x_0^2)}{1 + \alpha + x^2/x_0^2} \tag{23}$$

Thus, for the present case, eqs. (15) to (17) become:

$$I_a = \left(\frac{\hbar}{\kappa T}\right)^2 \frac{1}{BT}\int_0^{\theta/T} \frac{x^2\, e^x\, dx}{(e^x - 1)^2\ (1 + \alpha + x^2/x_0^2)}$$

$$= \left(\frac{\hbar}{\kappa T}\right)^2 \frac{1}{(1+\alpha)\ BT}\int_0^{\theta/T} \frac{x^2\, e^x\, dx}{(e^x - 1)^2\left[1 + \dfrac{x^2}{x_0^2\ (1+\alpha)}\right]}$$

$$= \left(\frac{\hbar}{\kappa T}\right)^2 \frac{1}{(1+\alpha)\ BT}\ I_2\ (\theta/T) \tag{24}$$

$$I_b = \alpha \int_0^{\theta/T} \frac{x^4 e^x \, dx}{(e^x - 1)^2 (1 + \alpha + x^2/x_0^2)} = \frac{\alpha}{(1+\alpha)} I_4 (\theta/T) \tag{25}$$

$$I_c = \left(\frac{\kappa T}{\hbar}\right)^2 \alpha BT \int_0^{\theta/T} \frac{x^6 e^x (1 + x^2/x_0^2) \, dx}{(e^x - 1)^2 (1 + \alpha + x^2/x_0^2)}$$

$$= \left(\frac{\kappa T}{\hbar}\right)^2 \frac{\alpha BT}{(1+\alpha)} \left[I_6 (\theta/T) + \frac{I_8 (\theta/T)}{x_0^2} \right] \tag{26}$$

Substituting eqs. (24) to (26) into eq. (14) yields

$$k_g = \frac{\kappa^2}{[2\pi^2 \hbar v (1+\alpha) B]} \left[I_2 (\theta/T) + \frac{\alpha I_4^2 (\theta/T)}{I_6 (\theta/T) + I_8 (\theta/T)/x_0^2} \right] \tag{27}$$

where $I_n (\theta/T)$ is the modified transport integral given by

$$I_n (\theta/T) = \int_0^{\theta/T} \frac{x^n e^x \, dx}{(e^x - 1)^2 \left[1 + \frac{x^2}{x_0^2 (1+\alpha)} \right]} \tag{28}$$

and x_0 is the reduced frequency at which the reciprocal relaxation times for U-processes and point-defect scattering are equal; that is (see eq. (32))

$$x_0 = \hbar\omega_0/\kappa T = \frac{\hbar}{\kappa} \sqrt{\frac{4\pi v^3 B}{a^3 \epsilon T}} \tag{29}$$

Equation (27) is for the lattice thermal conductivity as limited by both point-defect scattering and three-phonon anharmonic interactions. In the limit of vanishing point-defect scattering, when the thermal conductivity is limited by three-phonon anharmonic interactions only (denoted by k_u), x_0 becomes infinite so that the modified transport integral $I_n(\theta/T)$ reduces to the standard transport integral $J_n (\theta/T)$ and eq. (27) reduces to

$$k_u = \frac{\kappa^2}{[2\pi^2 \hbar v (1+\alpha) B]} [J_2 (\theta/T) + \alpha J_4^2 (\theta/T)/J_6 (\theta/T)] \tag{30}$$

where

$$J_n (\theta/T) = \int_0^{\theta/T} x^n e^x \, dx/(e^x - 1)^2 \tag{31}$$

k_u is the high-temperature lattice thermal conductivity of an isotopically pure element; in the case of an alloy it is the lattice thermal conductivity of an idealized "virtual" crystal in which each atom has the same average mass and volume of the alloy. Point defect scattering is that scattering which results from the fact that the actual atoms do not have these masses and volumes.

The quantity ϵ in the expression for the reciprocal relaxation time for point-defect scattering,

$$\tau_p^{-1} = \frac{a^3}{4\pi v^3} \epsilon \omega^4 \tag{32}$$

is calculated from the expression

$$\epsilon = y_L \left[\frac{M_L - M}{M} + \gamma \left(\frac{V_L - V}{V}\right)\right]^2 + y_H \left[\frac{M_H - M}{M_H} + \gamma \left(\frac{V_H - V}{V}\right)\right]^2 \tag{33}$$

where M and V are the average atomic mass and volume, y_L, M_L, and V_L are the atomic fraction, mass, and volume of the lighter element, y_H, M_H, and V_H are the corresponding values for the heavier element, and γ is the Grüneisen parameter. M is calculated in the usual way, γ is obtained by linear interpolation, and V is estimated from Vegard's law,

$$V^{1/3} = y\, V_1^{1/3} + (1-y)\, V_2^{1/3} \tag{34}$$

where y is the atomic fraction of the solute and V_1 and V_2 are the atomic volumes of the solute and solvent elements respectively. The mass defect terms are based on the results of Klemens [28] and Tavernier [29] who respectively treated the case of a light atom in a heavy matrix and that of a heavy atom in a light matrix. The difference lies in the response of the atom to the driving frequency of a wave; in the former case the atom can respond rapidly enough that the speed of oscillation may be considered unaffected so that the perturbation is proportional to the deviation from the average mass while in the latter case it is better to consider the momentum as being unaffected so that the perturbation is proportional to the difference of the reciprocals of the average and impurity masses. The distortion terms and the form of ϵ are based on the results of Ackerman and Klemens [30] who rediscovered the fact [31] that, contrary to what is often stated, the displacement field of a spherical impurity in an elastic continuum has a non-vanishing non-uniform dilation and used a treatment that retained the phase relationship between the effects of the dilation and mass defect. Equation (33) does not take into account the difference, Δf, in the force constant due to the mismatch of atomic bonds; however, neutron scattering and Mössbauer experiments [32,33] indicate that Δf is very small.

The coefficient in eq. (27) is the same as the coefficient in eq. (30) and is estimated from the latter. This is done by estimating θ in the manner described below, estimating

k_u of the virtual crystal at some temperature T' below the Debye temperature by linear interpolation between the values for the elements, and taking α equal to unity; it has been found that the values of k_g are not sensitive to small changes in α. Then k_g is estimated from the expression

$$k_g = k_u(T') \frac{I_2(\theta/T) + I_4^2(\theta/T)/[I_6(\theta/T) + I_8(\theta/T)/x_0^2]}{J_2(\theta/T') + J_4^2(\theta/T')/J_6(\theta/T')} \tag{35}$$

which, for a pure element, reduces to

$$k_g = k_u(T') \frac{J_2(\theta/T) + J_4^2(\theta/T)/J_6(\theta/T)}{J_2(\theta/T') + J_4^2(\theta/T')/J_6(\theta/T')} \tag{36}$$

Equations (35) and (36) are the equations used in our calculations for the lattice thermal conductivity of alloys and of pure elements, respectively. It should be noted that eq. (35) applies only to disordered solid-solution alloys.

The accuracy of the estimates obtained from eq. (35) clearly depends on the accuracy of the values of k_u for the virtual crystal. Experimental values of k_u for the elements, which essentially are the values of the lattice component of very dilute alloys, are available for only three of the metals included in this study: Cu, Au, and Ag. However, it was found that the experimental values for these metals each differed from the values obtained from the modified [34] Leibfried-Schlömann [35] equation by approximately the same factor. Accordingly initial estimates of the values of k_u for the other elements were obtained from this equation multiplied by the reciprocal of that factor, i.e.,

$$k_u T' = 5.7 \times 10^{-6} \frac{M \theta^3 V^{1/3}}{(\gamma + 0.5)^2} \tag{37}$$

where M, θ, γ, and V have the same meanings as before. It is unfortunate that in this equation the Debye temperature is raised to the third power, as the high temperature values of the Debye temperature obtained from various physical properties differ considerably. The values of the Debye temperatures and other parameters used in eq. (37) for the nine elements constituting the ten selected binary alloy systems covered in this work are given in Table 1.

While in some cases it was possible to improve on the initial estimates of k_u for some elements on the basis of experimental data for a range of compositions, in others it was not, and the estimates of the lattice thermal conductivities of alloys containing the latter elements are accordingly less reliable than those containing the former. While measurements of the thermal conductivity of very dilute alloys of additional elements would make possible more reliable estimates of alloy lattice thermal conductivity, in view of the

Table 1. Parameters for the Calculation of Lattice Thermal Conductivity of Elements Using Equation (37)[a]

Element	M	V	γ	θ
Aluminum	26.98154	10.00[b]	2.18	385
Copper	63.54	7.114	1.97	313
Gold	196.9665	10.22	3.09	160
Iron	55.847	7.094	1.81	373
Magnesium	24.305	14.00[c]	1.63	363
Nickel	58.71	6.593	2.00	312
Palladium	106.4	8.879	2.18	264
Silver	107.868	10.27	2.46	213
Zinc	65.38	9.165[d]	2.05	326

[a] The values of γ and θ are selected from ref. [36] with some of the values adjusted in order to be consistent with the experimental thermal conductivity data.

[b] In calculating ϵ, the molar volumes used for aluminum were 8.576 and 9.032. The first value corresponds to the size of aluminum atoms in copper as determined from the change in the lattice parameter of copper upon the addition of aluminum [37, Vol. 1]. The second value was obtained from the change in the volume of the primitive cell upon the addition of aluminum to magnesium as calculated from the changes in the lattice parameters of magnesium upon the addition of aluminum [37, Vol. 2].

[c] In calculating ϵ, the molar volume used for magnesium was 13.77 corresponding to the size of magnesium atoms in aluminum as determined from the change in the lattice parameter of aluminum upon the addition of magnesium [37, Vol. 2].

[d] In calculating ϵ, the molar volume used for zinc was 8.534 corresponding to the size of zinc atoms in copper as determined from the change in the lattice parameter of copper upon the addition of zinc [37, Vol. 2].

uncertainty of the separation of the electronic and lattice components of very dilute alloys at temperatures above that of the maximum of the lattice component, it would also be useful to have measurements of the thermal conductivity of some denser alloys of pairs of these elements in this temperature range.

The value of the Debye temperature, θ, for the upper limit of the integrals in eq. (35) is estimated from the value of k_u for the virtual crystal by means of the modified Leibfried-Schlömann equation, adjusted to yield values for the lattice component in agreement with those obtained from experimental data on very dilute alloys as described above:

$$\theta = 260 \left[\frac{(\gamma + 0.5)^2 k_u T}{MV^{1/3}}\right]^{1/3} \tag{38}$$

where γ is the Grüneisen parameter, and M and V are the average molar mass and volume.

Agreement between the values obtained from eq. (35) and those obtained from measurements of thermal conductivity for the various alloy systems is discussed in the text; in general, it was better for alloy systems exhibiting complete solid solubility. Another general result is that the values from eq. (35) for dilute alloys tended to be too low at the low end of this temperature range. A possible explanation of this discrepancy is that the present treatment does not take into account the "freezing out" of U-processes which occurs when the temperature is reduced to the point at which there are few phonons having wave vectors of sufficient length to participate in such processes. Such a reduction in U-processes could significantly reduce the thermal resistivity of dilute alloys but cause only a small decrease in the thermal resistivity of dense alloys.

The most important deficiency of the present treatment is that the analysis leading to eq. (35) does not include the electron-phonon interaction, for which an adequate theory has not yet been developed. As noted earlier, this interaction contributes significantly to the thermal resistivity in some transition element alloys; this is ture of the Pd-rich alloys considered in this study and eq. (35) could not be used to calculate the values of the lattice component in these alloys below their Debye temperatures.

At high temperatures the values obtained from eq. (35) are nearly the same as those from an approximate expression derived independently by Abeles [38] and Parrott [39], but there are significant differences below the Debye temperature, where the high temperature approximation used by these authors,

$$x^2 e^x/(e^x-1)^2 \simeq 1$$

ceases to be valid. However, because of a partial cancellation of errors these differences are much smaller than might be expected from the use of the high temperature approximation.

The use of eq. (35) rather than an approximate expression for the calculation of the lattice thermal conductivity is to some extent a reflection of the present availability of high-speed digital computers. The expression for the quantity ϵ, eq. (33), which takes into account the point-defect scattering due to both the mass difference and the distortion of the lattice and is first derived and given in the present work, is definitely an improvement of the theory.

3. DATA EVALUATION AND GENERATION OF RECOMMENDED VALUES

Due to the difficulties in accurate measurement of the thermal conductivity of solids and in exact characterization of test specimens, the available experimental data on thermal conductivity extracted from various research documents are usually widely divergent and subject to large uncertainty. It is therefore very important to critically evaluate the validity and reliability of the available data and related information, to resolve and reconcile the disagreements in conflicting data, and to generate recommended reference values.

In the critical evaluation of the validity and reliability of a particular set of thermal conductivity data, the temperature dependence of the data was examined and any unusual dependence or anomaly carefully investigated, the experimental technique reviewed to see whether the actual boundary conditions in the measurement agreed with those assumed in the theory and whether all the stray heat flows and losses were prevented or minimized and accounted for, the reduction of data examined to see whether all the necessary corrections had been appropriately applied, and the estimation of uncertainties checked to ensure that all the possible sources of errors had been considered.

Experimental data could be judged to be reliable only if all sources of systematic error had been eliminated or minimized and accounted for. Major sources of systematic error include unsuitable experimental method, poor experimental technique, poor instrumentation and poor sensitivity of measuring devices, sensors, or circuits, specimen and/or thermocouple contamination, unaccounted for stray heat flows, incorrect form factor, and perhaps most important, the mismatch between actual experimental boundary conditions and those assumed in the analytical model used to derive the value of thermal conductivity. These and other possible sources of errors have been carefully considered in critical evaluation of experimental data.

The uncertainty of a set of data depends, however, not only on the estimated error of the data but also on the adequacy of characterization of the material for which the data are reported. For instance, suppose a set of thermal conductivity data obtained for a cold-worked specimen of brass with a composition of 70.06% Cu, 28.77% Zn, and 1.17% Pb is accurate to within ±2%. If the author knew and reported his specimen only as 70:30 brass, the uncertainty of his data for a 70:30 brass would not be just ±2% but might exceed ±20%. It has been found in this and other studies that the chemical composition of a specimen reported by the author is often unreliable. This may be because in many cases the stated composition is the result of ladle analysis which the author obtained from the company who supplied the specimen and it can at best represent only the nominal composition; the actual composition varies from sample to sample. In other cases there is a strong tendency for only certain elements to be covered by a particular chemical analysis which could miss other important constituents. Furthermore, the chemical composition of a specimen may change

when it is measured at high temperatures. For binary alloys it has been found that the actual composition of a specimen may be inferred from its electrical resistivity if reported.

In the process of critical evaluation of experimental data described above, erroneous data were eliminated. The remaining data were then subjected to further critical analysis. For those test specimens for which experimental data on both thermal conductivity and electrical resistivity were reported, the electrical resistivity data were used for the calculation of electronic thermal conductivity values using eq. (12). Lattice thermal conductivity values were derived as the differences of the experimental k data and the calculated k_e values. These "experimental" k_g values derived from different sets of experimental k data were then intercompared and also compared with the calculated values from eq. (35) regarding their temperature dependence and magnitude. During these comparisons, the validity and reliability of the available experimental data could further be judged. The electrical resistivity data reported for the test specimens on which thermal conductivity measurements were made were also evaluated critically in connection with evaluation of all the electrical resistivity data available from the literature for each of the alloy systems, from which the recommended electrical resistivity values were generated.

As detailed in Section 2, the electronic component of the thermal conductivity was calculated from eq. (12), which is applicable to alloys in both the solid solution region and the mechanical mixture region. In this calculation, the recommended electrical resistivity values for the selected compositions of the present ten alloy systems and their constituent elements are available from ref. [7], the recommended thermoelectric power values are available from ref. [40], the recommended thermal conductivity values and the values of β for the pure elements are available from ref. [5], and the lattice thermal conductivity values of the pure elements used as corrections in the calculation of W_{ei} from eq. (7) are calculated from eq. (36). As examples to show the recommended electrical resistivity and thermoelectric power values used for the calculations, Figures 1 and 2 show the recommended electrical resistivity of the copper-nickel alloy system available from ref. [7] and Figures 3 and 4 show the recommended absolute thermoelectric power of the same alloy system.

The lattice thermal conductivity of alloys was calculated from eq. (35), in which the k_u values were calculated from eq. (37) using the values of the Debye temperatures and the other parameters given in Table 1. The value of the Debye temperature for the upper limit of the integrals in eq. (35) was estimated from eq. (38). It is important to note that eq. (35) is applicable only to disordered solid-solution alloys and only for moderate and high temperatures. Beyond the solid solution region and at low temperatures, the lattice thermal conductivity was first obtained as the difference of the experimental total thermal conductivity and the calculated electronic thermal conductivity. The "experimental" k_g values

were then graphically smoothed and synthesized to obtain the values for alloys of the selected compositions. In the solid-solution region and at moderate and high temperatures, the "experimental" k_g values were used to check the k_g values calculated from eq. (35). If there were disagreements and the "experimental" k_g values were considered more reliable, the values of the lattice thermal conductivity of the virtual crystals, k_u, used in eq. (35) would be adjusted so that the calculated k_g values were in agreement with the "experimental" k_g values.

In graphical smoothing and synthesis of data, cross-plotting from conductivity versus temperature to conductivity versus composition and vice versa was often used. Smooth curves were drawn which approximate the best fit to the conductivity data versus temperature, and points from the smoothed curves were used to construct conductivity versus composition curves for a convenient set of selected temperatures. In the conductivity versus composition graph, the families of isotherms were similar and any required smoothing of the data could be done more easily and with greater confidence than when working directly with the conductivity-temperature curves. The points from the smoothed curves were then used to construct conductivity-temperature curves for the selected compositions, and these curves were further smoothed. In the graphical smoothing process it is extremely important that the alloy phase diagrams [104,183,184] be constantly consulted and the phase boundaries between solid solutions and/or mechanical mixtures and the boundaries of magnetic transitions be kept in mind, so as to be aware of any possible discontinuity or sudden change of slope in the thermal conductivity curves.

The total thermal conductivity values were thus obtained as the sum of the k_e values calculated from eq. (12) and the k_g values derived from the "experimental" k_g values or calculated from eq. (35), which might have been adjusted to fit the "experimental" k_g values, if such values were available and reliable.

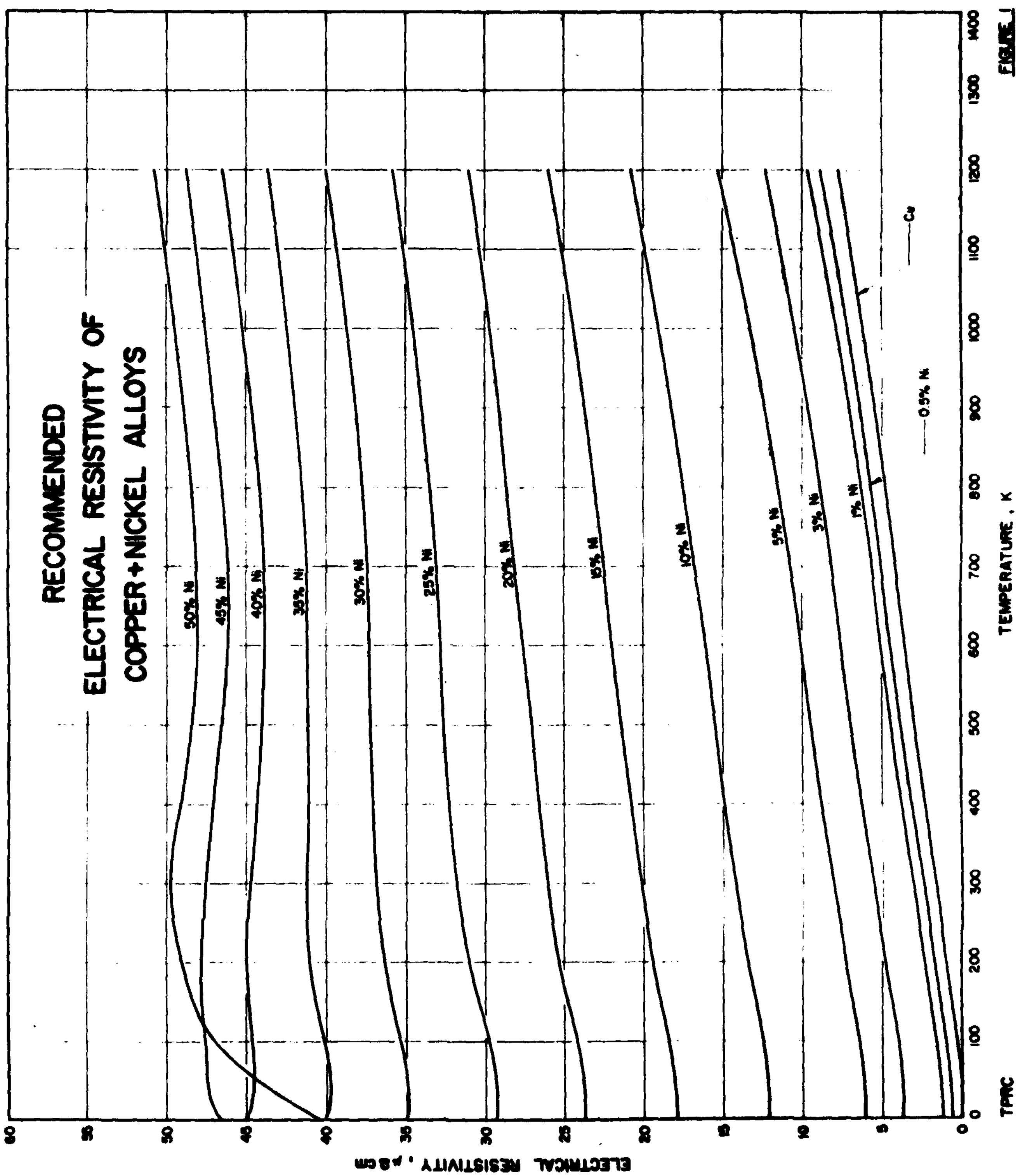
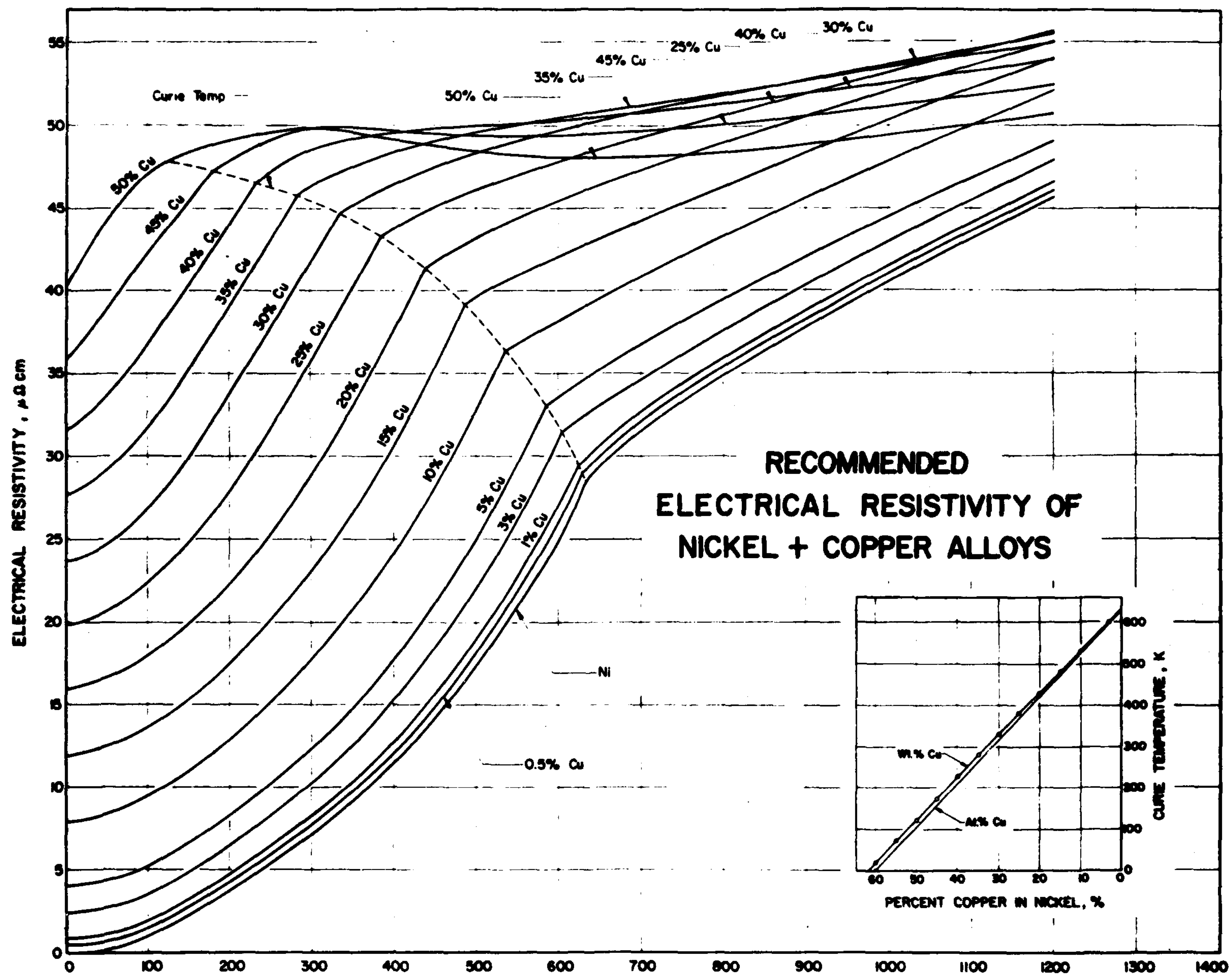

RECOMMENDED
ELECTRICAL RESISTIVITY OF
COPPER + NICKEL ALLOYS
50% Ni
45% Ni
40% Ni
35% Ni
30% Ni
25% Ni
20% Ni
15% Ni
10% Ni
5% Ni
3% Ni
1% Ni
0.5% Ni
Cu
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400
TEMPERATURE , K
0 5 10 15 20 25 30 35 40 45 50 55 60
ELECTRICAL RESISTIVITY , μΩ cm
TPRC

FIGURE 1



TPRC

FIGURE 2

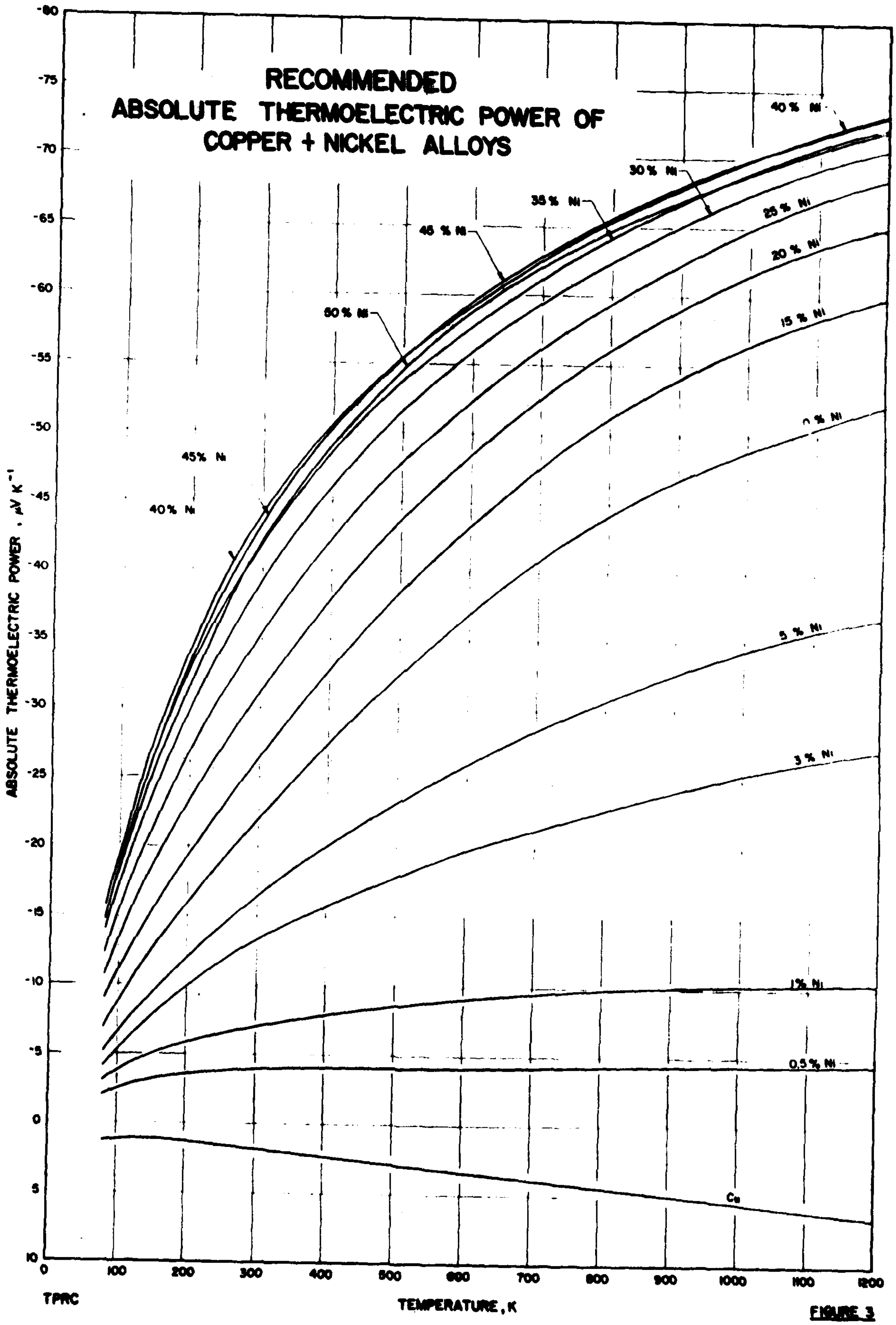
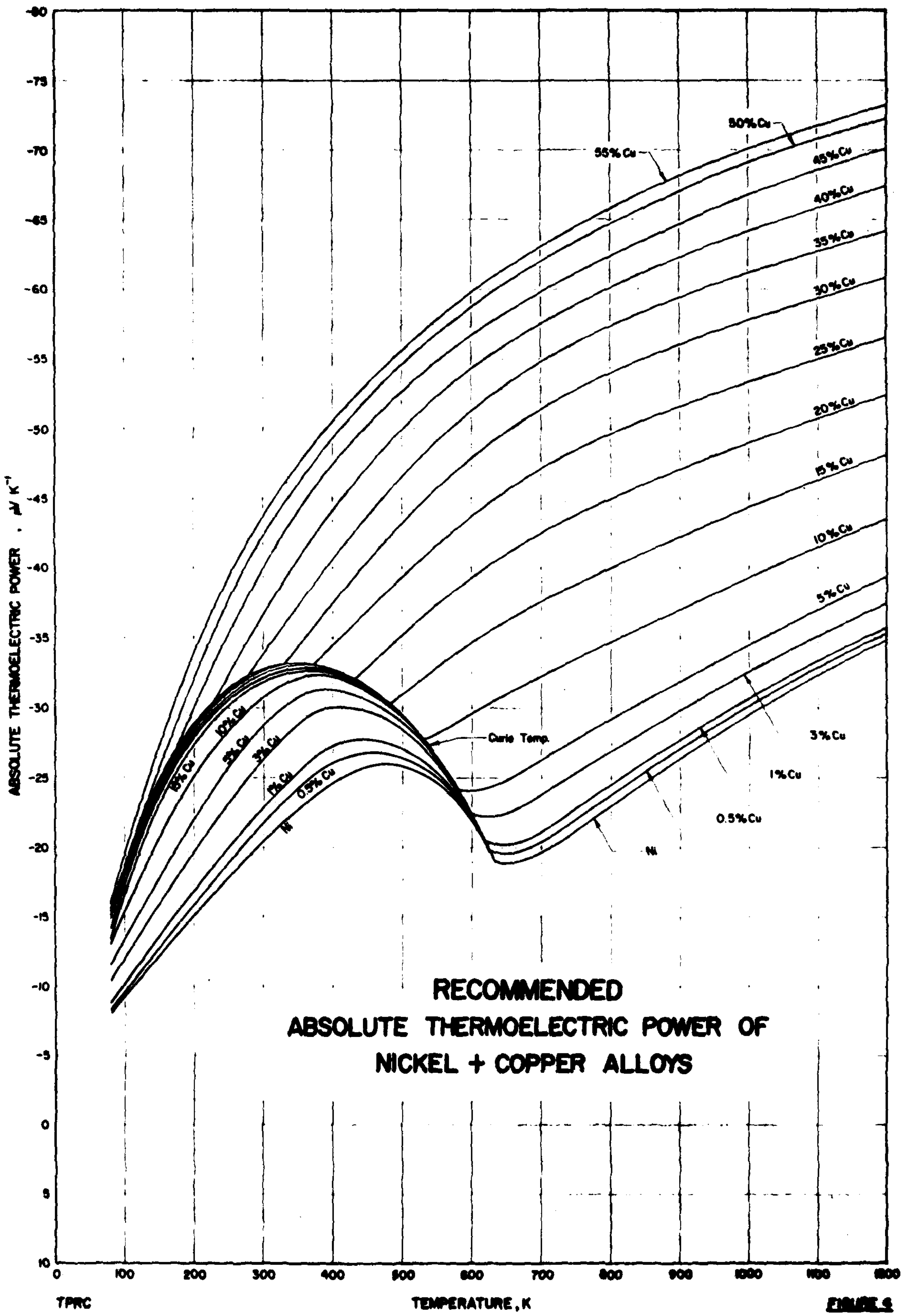

RECOMMENDED
ABSOLUTE THERMOELECTRIC POWER OF
COPPER + NICKEL ALLOYS
40 % Ni
30 % Ni
35 % Ni
25 % Ni
45 % Ni
20 % Ni
15 % Ni
50 % Ni
10 % Ni
45% Ni
40% Ni
5 % Ni
3 % Ni
1% Ni
0.5 % Ni
Cu
ABSOLUTE THERMOELECTRIC POWER, μV K⁻¹
-80
-75
-70
-65
-60
-55
-50
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
TEMPERATURE, K
TPRC

FIGURE 3



TPRC

FIGURE 6

4. THERMAL CONDUCTIVITY OF BINARY ALLOY SYSTEMS

In the following subsections the recommended (or provisional or typical) values for the total thermal conductivity, electronic thermal conductivity, and lattice thermal conductivity and the original experimental data for the thermal conductivity of the ten selected binary alloy systems are given, together with a discussion of each system, reviewing individual pieces of available data and information and discussing the considerations involved in arriving at the final assessment and recommendations. The conductivity values are for well-annealed disordered alloys.

In this work, the term "binary alloy system" refers to the full range of composition of two alloying elements and is signified by a hyphen between the two elements, such as aluminum-copper alloy system. The term "binary alloys" refers to a group of binary alloys in which the first alloying element is predominent and is signified by a plus between the two elements, such as aluminum + copper alloys.

In the figures and tables, weight percent is denoted by % and atomic percent by At.%. In the figures of recommended (or provisional or typical) values continuous (solid) curves represent recommended values, long-dashed curves represent provisional values, and dash-dot-dash curves represent typical values. The short-dashed portion of any of the above three kinds of curves represents values in the temperature ranges where no experimental data are available. In the tables of recommended (or provisional or typical) values, the values of residual electrical resistivity of the alloys are given, which is for the purpose of helping to characterize and identify the alloys for which the values are presented. The difference among recommended, provisional, and typical values is due to their ranges of uncertainties assigned. The ranges of uncertainties of recommended, provisional, and typical values are less than ±15%, between ±15% and ±30%, and greater than ±30%, respectively. In the tables on specimen characterization and measurement information, the code designations used for experimental methods for thermal conductivity determinations are as follows:

- C Comparative method
- E Direct electrical heating method
- F Forbes' bar method
- L Longitudinal heat flow method
- P Periodic or transient heat flow method
- R Radial heat flow method
- T Thermoelectrical method

In each of the subsections that follow, the thermal conductivity data and information are presented in the following order: discussion text, tables of recommended values, figures of recommended curves, figures of experimental data, and tables of specimen characterization and measurement information.

4.1. Aluminum-Copper Alloy System

The aluminum-copper alloy system does not form a continuous series of solid solutions. The maximum solid solubility of copper in aluminum is 5.70% (2.50 At.%) at 821 K and the solubility decreases to 0.1-0.2% (0.04-0.08 At.%) at 523 K. The maximum solid solubility of aluminum in copper is 9.4% (19.6 At.%) in the range from about 650 to 838 K and the solubility decreases at higher and lower temperatures. Thus the region of solid solution is limited. However, the equation derived for the calculation of the electronic component of thermal conductivity, eq. (12), is applicable to all phases, though the equation for the calculation of the lattice component, eq. (35), can be used only for solid solutions, as noted before in Sections 2 and 3. Beyond the solid solution region, the lattice thermal conductivity has been derived from the experimental total thermal conductivity and the calculated electronic component.

There are 188 sets of experimental data available for the thermal conductivity of this alloy system. However, of the 49 data sets for Al + Cu alloys listed in Table 3 and shown in Figure 7, 10 sets are merely single data points around room temperature and 27 sets cover only a narrow temperature range from around room temperature to about 500 K. Of the 139 data sets for Cu + Al alloys listed in Table 4 and shown in Figure 8, 20 sets are single data points, 15 sets cover the narrow temperature range from around room temperature to about 500 K, and 84 sets are for temperatures below 4.5 K.

For the Al + Cu alloys, all measurements were made between room temperature and 800 K except four (Al + Cu curves 6-8, and 16) which were measured down to about 80 K for specimens containing 4.0, 8.0, and 15.0% Cu [41,42] and except the two of Satterthwaite [43] who investigated the thermal conductivity of a specimen containing 0.3% Cu in both the superconducting and normal states (Al + Cu curves 25 and 26). A thermal conductivity versus composition curve for 300 K was constructed following mainly the data of Griffiths and Schofield [44] (Al + Cu curves 1-5) and of Smith [45] (Al + Cu curves 12-15). Electronic thermal conductivity values at 300 K were calculated from eq. (12) using electrical resistivity reported in [7], thermoelectric power reported in [40], thermal conductivity of aluminum and the value of β reported in [5], and lattice thermal conductivity of aluminum calculated from eq. (36). These k_e values were also plotted on the conductivity-composition graph. The differences k_g between the experimental total thermal conductivity k and the calculated electronic component k_e for the various compositions were taken. These k_g values were extrapolated to higher temperatures up to the solidus points according to the temperature dependence of eq. (35) and to lower temperatures according to the pattern of k_g curves of aluminum-copper system derived from the available experimental k and the calculated k_e around the region of maximum k_g and according to T^2 dependence at lower temperatures assuming k_g to be negligible at 1 K. The values were then adjusted so that the extrapolated

k_g values plus their corresponding k_e values yield total k values which fit the experimental data in those regions. The total thermal conductivity values were then obtained by adding the calculated values of k_e to the adjusted extrapolated values of k_g. The results are in agreement with the data of Griffiths and Schofield [44] (Al + Cu curves 1-5), Smith [45] (Al + Cu curves 12-14), and Griffiths and Shakespear [46] (Al + Cu curve 17) above room temperature to within 5%. No appropriate comparison is available below room temperature.

On the copper-rich side, several measurements were made between 4 K and 80 K [48] (Cu + Al curves 111-121) for alloys containing 4.07, 0.43, and 6.97% Al. The conductivity-composition curve at 300 K was constructed, based mainly on the data of Smith and Palmer [49] (Cu + Al curves 2-9) and Smith [45] (Cu + Al curves 14-18), which are considered reliable. The k_e values were calculated from eq. (12) and those at 300 K were plotted on the conductivity-composition graph. The differences k_g between k and k_e were obtained for all compositions. These k_g values were adjusted so that their extrapolations to lower temperatures, according to the method described above for Al + Cu alloys, fit the k_g values derived from experimental data of Chu and Lipschultz [48] (Cu + Al curves 111-121) and of Friedman [50] (Cu + Al curves 122-126). Above 300 K the k_g values were extrapolated to the solidus points. The total thermal conductivity values were then obtained by adding the calculated values of k_e to the adjusted extrapolated values of k_g. Because of the lack of experimental electrical resistivity data, no total k values are given below 200 K for the alloy with 10% Al, below 300 K for the alloy with 15% Al, and at temperatures other than 300 K for the alloy with 20% Al. The resulting recommended values at low temperatures are in agreement with the data of Salter and Charsley [51] (Cu + Al curves 19-26), Kusunoki and Suzuki [53] (Cu + Al curves 45-52), Chu and Lipschultz [48] (Cu + Al curves 111-121), and Friedman [50] (Cu + Al curves 122-126) to within 6%, and those at higher temperatures are in agreement with the data of Smith and Palmer [49] (Cu + Al curves 2-9), Hanson and Rodgers [47] (Cu + Al curves 10-13), Inouye [55] (Cu + Al curves 37 and 38), Smith and Palmer [49] (Cu + Al curve 78), and Aliev [116] (Cu + Al curves 57-65 and 67) to within 10%.

The resulting recommended values for k, k_e, and k_g are tabulated in Table 2 for 25 alloy compositions. These values are for well-annealed alloys. The values for k are also shown in Figures 5 and 6. For most of the alloy compositions, the temperature range covered is from 4 K to the temperature where melting starts. The values of residual electrical resistivity for the alloys are also given in Table 2. The uncertainties of the k values are stated in a footnote to Table 2, while the uncertainties of the k_e and k_g values are indicated by their being designated as recommended, provisional, or typical values. The ranges of uncertainties of recommended, provisional, and typical values are less than ±15%, between ±15 and ±30%, and greater than ±30%, respectively.

TABLE 2. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Al: 99.50% (99.79 At.%); Cu: 0.50% (0.21 At.%); ρ_o = 0.0600 μΩcm

T	k	k_e	k_g
4	1.58*		
6	2.36*		
8	3.11*		
10	3.81*		
15	5.46*		
20	6.73*		
25	7.56*	7.30	0.265‡
30	8.06*	7.78	0.285‡
40	8.22*	7.94	0.285‡
50	7.36*	7.09	0.265‡
60	5.99*	5.75	0.241‡
70	4.74*	4.52	0.218‡
80	3.77*	3.57	0.199‡
90	3.11*	2.93	0.183‡
100	2.78*	2.61	0.169‡
150	2.30*	2.18	0.123‡
200	2.24*	2.14	0.0968‡
250	2.25*	2.17	0.0801‡
273	2.26*	2.19	0.0745‡
300	2.28	2.21	0.0685‡
350	2.31	2.25	0.0596‡
400	2.32	2.27	0.0530‡
500	2.29	2.25	0.0430‡
600	2.25	2.21	0.0362‡
700	2.19	2.16	0.0312‡
800	2.13*	2.10	0.0273‡
900	2.06*	2.04	0.0243‡
919	2.05*	2.03	0.0238‡

Al: 99.00% (99.57 At.%); Cu: 1.00% (0.43 At.%); ρ_o = 0.1203 μΩcm

T	k	k_e	k_g
4	0.814*		
6	1.23*		
8	1.65*		
10	2.05*		
15	3.04*		
20	3.92*		
25	4.64*	4.42	0.221‡
30	5.14*	4.90	0.239‡
40	5.64*	5.40	0.239‡
50	5.45*	5.23	0.221‡
60	4.80*	4.60	0.202‡
70	4.04*	3.85	0.185‡
80	3.35*	3.18	0.170‡
90	2.85*	2.69	0.157‡
100	2.58*	2.43	0.145‡
150	2.20*	2.09	0.107‡
200	2.15*	2.07	0.0847‡
250	2.17*	2.10	0.0704‡
273	2.18*	2.12	0.0652‡
300	2.21	2.15	0.0602‡
350	2.25	2.20	0.0525‡
400	2.26	2.21	0.0467‡
500	2.24	2.20	0.0382‡
600	2.19	2.16	0.0322‡
700	2.15	2.12	0.0279‡
800	2.08*	2.06	0.0245‡
900	2.02*	2.00	0.0219‡
910	2.01*	1.99	0.0217‡

Al: 97.00% (98.70 At.%); Cu: 3.00% (1.30 At.%); ρ_o = 0.340 μΩcm

T	k	k_e	k_g
4	0.292*		
6	0.442*		
8	0.593*		
10	0.741*		
15	1.10*		
20	1.45*		
25	1.75*	1.61	0.139‡
30	2.02*	1.87	0.152‡
40	2.44*	2.28	0.155‡
50	2.68*	2.53	0.147‡
60	2.70*	2.56	0.138‡
70	2.54*	2.41	0.127‡
80	2.33*	2.21	0.118‡
90	2.11*	2.00	0.110‡
100	1.99*	1.89	0.102‡
150	1.89*	1.81	0.0758‡
200	1.90*	1.84	0.0607‡
250	1.94*	1.89	0.0509‡
273	1.97*	1.92	0.0474‡
300	1.99*	1.95	0.0438‡
350	2.04	2.00	0.0386‡
400	2.07	2.04	0.0345‡
500	2.07	2.04	0.0285‡
600	2.05	2.03	0.0243‡
700	2.02	2.00	0.0212‡
800	1.97*	1.95	0.0189‡
864	1.94*	1.92	0.0177‡

Al: 95.00% (97.81 At.%); Cu: 5.00% (2.19 At.%); ρ_o = 0.532 μΩcm

T	k	k_e	k_g
4	0.189*	0.183	0.00578‡
6	0.288*	0.275	0.0130‡
8	0.388*	0.366	0.0222‡
10	0.489*	0.456	0.0330‡
15	0.738*	0.677	0.0610‡
20	0.977*	0.892	0.0849‡
25	1.19*	1.09	0.102‡
30	1.39*	1.28	0.112‡
40	1.71*	1.59	0.117‡
50	1.92*	1.81	0.112‡
60	2.00*	1.89	0.106‡
70	1.98*	1.88	0.0985‡
80	1.89*	1.80	0.0916‡
90	1.79*	1.70	0.0857‡
100	1.72*	1.64	0.0804‡
150	1.67*	1.61	0.0612‡
200	1.72*	1.67	0.0495‡
250	1.79*	1.75	0.0416‡
273	1.82*	1.78	0.0389‡
300	1.85	1.81	0.0360‡
350	1.90	1.87	0.0319‡
400	1.93	1.90	0.0285‡
500	1.95	1.93	0.0237‡
600	1.94	1.92	0.0203‡
700	1.92	1.90	0.0177‡
800	1.89*	1.87	0.0157‡
831	1.88*	1.86	0.0152‡

† Uncertainties of the total thermal conductivity, k, are as follows:
99.50 Al - 0.50 Cu: ±6% below 200 K, and ±3% above 200 K.
99.00 Al - 1.00 Cu: ±6% below 200 K, and ±3% above 200 K.
97.00 Al - 3.00 Cu: ±8% below 100 K, ±5% between 100 and 500 K, and ±6% above 500 K.
95.00 Al - 5.00 Cu: ±8% below 100 K, ±5% between 100 and 500 K, and ±6% above 500 K.

‡ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 2. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Al: 90.00% (95.49 At.%), Cu: 10.00% (4.51 At.%); ρ_o = 0.888 $\mu\Omega$cm

T	k	k_e	k_g
4	0.115*	0.110	0.00466‡
6	0.176*	0.165	0.0105‡
8	0.238*	0.220	0.0179‡
10	0.300*	0.273	0.0266‡
15	0.455*	0.406	0.0491‡
20	0.604*	0.536	0.0684‡
25	0.741*	0.659	0.0823‡
30	0.865*	0.774	0.0905‡
40	1.06*	0.962	0.0942‡
50	1.24*	1.15	0.0905‡
60	1.35*	1.26	0.0853‡
70	1.38*	1.30	0.0794‡
80	1.38*	1.31	0.0738‡
90	1.35	1.28	0.0691‡
100	1.33	1.27	0.0647‡
150	1.39	1.34	0.0493‡
200	1.47	1.43	0.0399‡
250	1.55	1.52	0.0335‡
273	1.58	1.55	0.0313‡
300	1.61	1.58	0.0290‡
350	1.67	1.64	0.0257‡
400	1.71	1.69	0.0229‡
500	1.74	1.72	0.0191‡
600	1.75	1.73	0.0163‡
700	1.74	1.73	0.0142‡
800	1.73	1.71	0.0127‡
821	1.72	1.71	0.0124‡

Al: 85.00% (93.03 At.%), Cu: 15.00% (6.97 At.%); ρ_o = 1.118 $\mu\Omega$cm

T	k	k_e	k_g
4	0.0913*	0.0870	0.00426‡
6	0.140*	0.130	0.00956‡
8	0.189*	0.173	0.0163‡
10	0.240*	0.216	0.0243‡
15	0.365*	0.320	0.0449‡
20	0.484*	0.421	0.0625‡
25	0.594*	0.519	0.0752‡
30	0.694*	0.611	0.0827‡
40	0.862*	0.776	0.0861‡
50	0.993*	0.910	0.0827‡
60	1.09*	1.01	0.0779‡
70	1.14*	1.07	0.0725‡
80	1.16*	1.09	0.0674‡
90	1.16	1.10	0.0631‡
100	1.16	1.10	0.0592‡
150	1.26	1.21	0.0451‡
200	1.34	1.30	0.0365‡
250	1.42	1.39	0.0306‡
273	1.45	1.42	0.0286‡
300	1.49	1.46	0.0265‡
350	1.54	1.52	0.0235‡
400	1.58	1.56	0.0209‡
500	1.62	1.60	0.0174‡
600	1.64*	1.63	0.0149‡
700	1.64*	1.63	0.0130‡
800	1.62*	1.61	0.0116‡
821	1.62*	1.61	0.0113‡

Al: 80.00% (90.40 At.%), Cu: 20.00% (9.60 At.%); ρ_o = 1.312 $\mu\Omega$cm

T	k	k_e	k_g
4	0.0786*	0.0745	0.00406‡
6	0.121*	0.112	0.00912‡
8	0.165*	0.149	0.0156‡
10	0.209*	0.186	0.0232‡
15	0.317*	0.274	0.0428‡
20	0.420*	0.360	0.0597‡
25	0.515*	0.443	0.0718‡
30	0.602*	0.522	0.0789‡
40	0.749*	0.667	0.0822‡
50	0.866*	0.787	0.0789‡
60	0.951*	0.877	0.0744‡
70	1.01*	0.938	0.0692‡
80	1.03*	0.970	0.0644‡
90	1.04*	0.984	0.0602‡
100	1.06*	1.00	0.0565‡
150	1.15*	1.11	0.0430‡
200	1.25*	1.22	0.0348‡
250	1.33*	1.30	0.0292‡
273	1.37*	1.34	0.0273‡
300	1.40	1.37	0.0253‡
350	1.46	1.44	0.0224‡
400	1.50*	1.48	0.0200‡
500	1.54*	1.52	0.0166‡
600	1.56*	1.55	0.0142‡
700	1.56*	1.55	0.0124‡
800	1.55*	1.54	0.0111‡
821	1.55*	.54	0.0109‡

Al: 75.00% (87.60 At.%), Cu: 25.00% (12.40 At.%); ρ_o = 1.482 $\mu\Omega$cm

T	k	k_e	k_g
4	0.0699*	[illegible]	[illegible]
6	0.108*	0.0983	[illegible]
8	0.147*	0.132	0.0158‡
10	0.188*	0.166	[illegible]
15	0.285*	0.243	[illegible]
20	0.378*	0.319	0.0595‡
25	0.462*	0.382	0.0798‡
30	0.540*	0.463	0.0774‡
40	0.674*	0.593	0.0806‡
50	0.777*	0.700	0.0774‡
60	0.857*	0.784	0.0729‡
70	0.911*	0.843	0.0679‡
80	0.943*	0.888	0.0631‡
90	0.960*	0.901	0.0591‡
100	0.978*	0.923	0.0554‡
150	1.09*	1.05	0.0422‡
200	1.18*	1.15	0.0361‡
250	1.27*	1.24	0.0297‡
273	1.30*	1.27	0.0268‡
300	1.33*	1.31	0.0246‡
350	1.39*	1.37	0.0219‡
400	1.43*	1.41	0.0196‡
500	1.47*	1.45	0.0163‡
600	1.50*	1.49	0.0140‡
700	1.50*	1.49	0.0123‡
800	1.50*	1.49	0.0106‡
821	1.50*	1.49	0.0106‡

† Uncertainties of the total thermal conductivity, k, are as follows:
- 90.00 Al - 10.00 Cu: ±8% below 100 K, ±5% between 100 and 500 K, and ±6% above 500 K.
- 85.00 Al - 15.00 Cu: ±10% below 100 K, ±5% between 100 and 500 K, and ±6% above 500 K.
- 80.00 Al - 20.00 Cu: ±10% below 100 K, ±5% between 100 and 500 K, and ±7% above 500 K.
- 75.00 Al - 25.00 Cu: ±10% below 100 K, ±5% between 100 and 500 K, and ±7% above 500 K.

‡ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 2. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Al: 70.00% (84.60 At.%) Cu: 30.00% (15.40 At.%)				Al: 65.00% (81.39 At.%) Cu: 35.00% (18.61 At.%)				Al: 60.00% (77.94 At.%) Cu: 40.00% (22.06 At.%)				Al: 55.00% (74.22 At.%) Cu: 45.00% (25.70 At.%)			
ρ_0 = 1.623 μΩcm				ρ_0 = 1.754 μΩcm				ρ_0 = 1.883 μΩcm				ρ_0 = 2.02 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0641*	0.0602	0.00392‡	4	0.0596*	0.0557	0.00392‡	4	0.0558*	0.0519	0.00394‡	4	0.0524*	0.0484	0.00395‡
6	0.0993*	0.0905	0.00880‡	6	0.0924*	0.0836	0.00880‡	6	0.0866*	0.0778	0.00884‡	6	0.0812*	0.0723	0.00887‡
8	0.135*	0.120	0.0150‡	8	0.127*	0.112	0.0150‡	8	0.118*	0.103	0.0151‡	8	0.111*	0.0955	0.0152‡
10	0.172*	0.150	0.0223‡	10	0.160*	0.138	0.0223‡	10	0.150*	0.128	0.0224‡	10	0.142*	0.119	0.0225‡
15	0.262*	0.221	0.0413‡	15	0.244*	0.203	0.0413‡	15	0.228*	0.187	0.0415‡	15	0.217*	0.175	0.0417‡
20	0.348*	0.290	0.0575‡	20	0.324*	0.267	0.0575‡	20	0.306*	0.248	0.0578‡	20	0.290*	0.232	0.0580‡
25	0.425*	0.356	0.0693‡	25	0.399*	0.330	0.0693‡	25	0.377*	0.307	0.0696‡	25	0.357*	0.287	0.0700‡
30	0.497*	0.421	0.0761‡	30	0.466*	0.390	0.0761‡	30	0.439*	0.363	0.0764‡	30	0.418*	0.339	0.0786‡
40	0.618*	0.539	0.0793‡	40	0.579*	0.500	0.0793‡	40	0.546*	0.466	0.0796‡	40	0.517*	0.437	0.0799‡
50	0.724*	0.638	0.0861‡	50	0.669*	0.593	0.0761‡	50	0.631*	0.555	0.0764‡	50	0.597*	0.520	0.0768‡
60	0.787*	0.715	0.0718‡	60	0.740*	0.668	0.0718‡	60	0.700*	0.628	0.0721‡	60	0.662*	0.590	0.0724‡
70	0.841*	0.774	0.0668‡	70	0.793*	0.726	0.0668‡	70	0.751*	0.684	0.0670‡	70	0.711*	0.644	0.0673‡
80	0.877*	0.815	0.0621‡	80	0.830*	0.768	0.0621‡	80	0.787*	0.725	0.0623‡	80	0.748*	0.685	0.0626‡
90	0.900*	0.842	0.0581‡	90	0.856*	0.798	0.0581‡	90	0.813*	0.755	0.0583‡	90	0.778*	0.719	0.0586‡
100	0.924*	0.869	0.0545‡	100	0.880*	0.825	0.0545‡	100	0.850*	0.785	0.0547‡	100	0.805*	0.750	0.0549‡
150	1.04*	0.998	0.0415‡	150	0.998*	0.957	0.0415‡	150	0.963*	0.921	0.0417‡	150	0.929*	0.887	0.0418‡
200	1.14*	1.11	0.0336‡	200	1.10*	1.07	0.0336‡	200	1.06*	1.03	0.0337‡	200	1.03*	0.993	0.0338‡
250	1.22*	1.19	0.0282‡	250	1.17*	1.14	0.0282‡	250	1.14*	1.11	0.0283‡	250	1.10*	1.07	0.0284‡
273	1.25*	1.22	0.0263‡	273	1.21*	1.18	0.0263‡	273	1.17*	1.14	0.0264‡	273	1.13*	1.10	0.0266‡
300	1.28	1.26	0.0244‡	300	1.24*	1.22	0.0244‡	300	1.20	1.18	0.0245‡	300	1.17	1.15	0.0246‡
350	1.34	1.32	0.0216‡	350	1.29*	1.27	0.0216‡	350	1.25	1.23	0.0217‡	350	1.22	1.20	0.0218‡
400	1.39*	1.38	0.0193‡	400	1.33*	1.31	0.0193‡	400	1.29*	1.27	0.0194‡	400	1.26*	1.24	0.0194‡
500	1.42*	1.40	0.0160‡	500	1.38*	1.36	0.0160‡	500	1.34*	1.32	0.0161‡	500	1.32*	1.30	0.0162‡
600	1.45*	1.44	0.0137‡	600	1.40*	1.39	0.0137‡	600	1.37*	1.36	0.0138‡	600	1.34*	1.33	0.0138‡
700	1.46*	1.45	0.0120‡	700	1.42*	1.41	0.0120‡	700	1.38*	1.37	0.0120‡	700	1.35*	1.34	0.0121‡
800	1.45*	1.44	0.0107‡	800	1.41*	1.40	0.0107‡	800	1.38*	1.37	0.0107‡	800	1.35*	1.34	0.0108‡
821	1.45*	1.44	0.0105‡	821	1.41*	1.40	0.0105‡	821	1.38*	1.37	0.0105‡	821	1.35*	1.34	0.0106‡

† Uncertainties of the total thermal conductivity, k, are as follows:
70.00 Al - 30.00 Cu: ±10% below 100 K, ±5% between 100 and 500 K, and ±7% above 500 K.
65.00 Al - 35.00 Cu: ±12% below 100 K, ±5% between 100 and 500 K, and ±7% above 500 K.
60.00 Al - 40.00 Cu: ±12% below 100 K, ±5% between 100 and 500 K, and ±7% above 500 K.
55.00 Al - 45.00 Cu: ±12% below 80 K, ±5% between 80 and 500 K, and ±7% above 500 K.

‡ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 2. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Al: 50.00% (70.19 At.%) Cu: 50.00% (29.81 At.%)				Al: 45.00% (65.83 At.%) Cu: 55.00% (34.17 At.%)				Al: 40.00% (61.09 At.%) Cu: 60.00% (38.91 At.%)				Al: 35.00% (55.91 At.%) Cu: 65.00% (44.09 At.%)			
ρ_0 = 2.25 μΩ cm				ρ_0 = 2.59 μΩ cm				ρ_0 = 3.25 μΩ cm				ρ_0 = 4.42 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0474*	0.0434	0.00398‡	4	0.0420*‡	0.0380	0.00400‡	4	0.0342*‡	0.0302	0.00402‡	4	0.0269*‡	0.0228	0.00409‡
6	0.0736*	0.0647	0.00894‡	6	0.0659*‡	0.0569	0.00900‡	6	0.0541*‡	0.0450	0.00909‡	6	0.0430*‡	0.0338	0.00922‡
8	0.101*	0.0857	0.0153‡	8	0.0909*‡	0.0755	0.0154‡	8	0.0753*‡	0.0597	0.0156‡	8	0.0605*‡	0.0447	0.0158‡
10	0.130*	0.107	0.0227‡	10	0.117*‡	0.0942	0.0229‡	10	0.0974*‡	0.0744	0.0230‡	10	0.0786*‡	0.0552	0.0234‡
15	0.200*	0.158	0.0420‡	15	0.181*‡	0.139	0.0422‡	15	0.154*‡	0.111	0.0426‡	15	0.125*‡	0.0816	0.0434‡
20	0.265*	0.206	0.0585‡	20	0.242*‡	0.183	0.0590‡	20	0.206*‡	0.146	0.0595‡	20	0.168*‡	0.108	0.0603‡
25	0.328*	0.258	0.0704‡	25	0.296*‡	0.225	0.0708‡	25	0.252*‡	0.181	0.0714‡	25	0.206*‡	0.133	0.0730‡
30	0.383*	0.306	0.0774‡	30	0.344*‡	0.267	0.0775‡	30	0.293*‡	0.215	0.0782‡	30	0.237*‡	0.158	0.0793‡
40	0.475*	0.394	0.0806‡	40	0.426*‡	0.345	0.0810‡	40	0.361*‡	0.279	0.0817‡	40	0.290*‡	0.207	0.0830‡
50	0.548*	0.471	0.0774‡	50	0.494*‡	0.416	0.0779‡	50	0.415*‡	0.337	0.0784‡	50	0.332*‡	0.252	0.0797‡
60	0.609*	0.536	0.0729‡	60	0.550*‡	0.477	0.0730‡	60	0.463*‡	0.389	0.0737‡	60	0.368*‡	0.293	0.0748‡
70	0.658*	0.590	0.0679‡	70	0.596*‡	0.528	0.0680‡	70	0.499*‡	0.430	0.0690‡	70	0.400*‡	0.330	0.0697‡
80	0.695*	0.632	0.0631‡	80	0.631*‡	0.568	0.0634‡	80	0.535*‡	0.471	0.0640‡	80	0.431*‡	0.366	0.0650‡
90	0.726*	0.667	0.0591‡	90	0.661*	0.602	0.0594‡	90	0.565*	0.505	0.0599‡	90	0.457*	0.396	0.0610‡
100	0.752*	0.696	0.0554‡	100	0.689*	0.633	0.0558‡	100	0.594*	0.538	0.0562‡	100	0.483*	0.426	0.0571‡
150	0.880*	0.838	0.0422‡	150	0.814*	0.772	0.0425‡	150	0.722*	0.679	0.0429‡	150	0.608*	0.565	0.0435‡
200	0.979*	0.945	0.0341‡	200	0.915*	0.881	0.0343‡	200	0.820*	0.785	0.0345‡	200	0.691*	0.656	0.0350‡
250	1.06*	1.03	0.0287‡	250	0.996*	0.967	0.0289‡	250	0.902*	0.873	0.0291‡	250	0.772*	0.742	0.0296‡
273	1.09*	1.06	0.0268‡	273	1.03*	1.00	0.0270‡	273	0.933*	0.906	0.0271‡	273	0.804*	0.776	0.0276‡
300	1.12	1.10	0.0248‡	300	1.06	1.04	0.0250‡	300	0.968	0.943	0.0252‡	300	0.840	0.814	0.0256‡
350	1.18	1.16	0.0219‡	350	1.12*	1.10	0.0220‡	350	1.02*	1.00	0.0223‡	350	0.897*	0.874	0.0226‡
400	1.22*	1.20	0.0196‡	400	1.16*	1.14	0.0197‡	400	1.07*	1.05	0.0199‡	400	0.943*	0.923	0.0202‡
500	1.28*	1.26	0.0163‡	500	1.22*	1.20	0.0164‡	500	1.14*	1.12	0.0165‡	500	1.01*	0.997	0.0168‡
600	1.30*	1.29	0.0140‡	600	1.25*	1.24	0.0140‡	600	1.17*	1.16	0.0141‡	600	1.06*	1.05	0.0144‡
700	1.32*	1.31	0.0122‡	700	1.27*	1.26	0.0122‡	700	1.20*	1.19	0.0123‡	700	1.10*	1.08	0.0126‡
800	1.32*	1.31	0.0108‡	800	1.28*	1.27	0.0109‡	800	1.22*	1.21	0.0109‡	800	1.12*	1.11	0.0111‡
821	1.32*	1.31	0.0106‡	864	1.29*	1.28	0.0101‡	864	1.23*	1.22	0.0102‡	864	1.14*	1.13	0.0104‡

† Uncertainties of the total thermal conductivity, k, are as follows:
50.00 Al - 50.00 Cu: ±12% below 80 K, ±5% between 80 and 500 K, and ±7% above 500 K.
45.00 Al - 55.00 Cu: ±15% below 80 K, ±10% between 80 and 200 K, and ±7% above 200 K.
40.00 Al - 60.00 Cu: ±15% below 80 K, ±10% between 80 and 200 K, and ±8% above 200 K.
35.00 Al - 65.00 Cu: ±20% below 80 K, ±10% between 80 and 200 K, and ±8% above 200 K.

‡ Provisional value.

‡ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 2. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM (continued)*

[Temperature, T, K; Thermal Conductivity, k, W cm⁻¹ K⁻¹; Electronic Thermal Conductivity, k_e, W cm⁻¹ K⁻¹; Lattice Thermal Conductivity, k_g, W cm⁻¹ K⁻¹]

Al: 30.00% (50.23 At.%), Cu: 70.00% (49.77 At.%); ρ_0 = 6.61 μΩ cm

T	k	k_e	k_g
4	0.0191*‡	0.0149	0.00416§
6	0.0318*‡	0.0224	0.00938§
8	0.0457*‡	0.0297	0.0160‡
10	0.0606*‡	0.0370	0.0236‡
15	0.0987*‡	0.0547	0.0440§
20	0.134*‡	0.0723	0.0614‡
25	0.163*‡	0.0896	0.0737‡
30	0.188*‡	0.107	0.0806‡
40	0.224*‡	0.140	0.0842‡
50	0.253*‡	0.172	0.0810§
60	0.277*‡	0.201	0.0760§
70	0.299*‡	0.228	0.0710§
80	0.322*‡	0.256	0.0662‡
90	0.343*	0.281	0.0620§
100	0.363*	0.303	0.0600§
150	0.455*	0.411	0.0442‡
200	0.534*	0.499	0.0357‡
250	0.606*	0.576	0.0300§
273	0.635*	0.607	0.0280§
300	0.668	0.642	0.0260§
350	0.722*	0.699	0.0230‡
400	0.768*	0.748	0.0205‡
500	0.842*	0.825	0.0170‡
600	0.898*	0.883	0.0146§
700	0.941*	0.928	0.0127§
800	0.971*	0.960	0.0113‡
864	0.983*	0.972	0.0106§

Al: 25.00% (43.98 At.%), Cu: 75.00% (56.02 At.%); ρ_0 = 12.4 μΩ cm

T	k	k_e	k_g
4	0.0121*‡	0.00788	0.00424‡
6	0.0214*‡	0.0118	0.00955‡
8	0.0321*‡	0.0158	0.0163‡
10	0.0439*‡	0.0197	0.0242‡
15	0.0743*‡	0.0294	0.0449‡
20	0.102*‡	0.0391	0.0627‡
25	0.124*‡	0.0485	0.0750‡
30	0.140*‡	0.0580	0.0823‡
40	0.163*‡	0.0766	0.0860‡
50	0.177*‡	0.0947	0.0825‡
60	0.190*‡	0.112	0.0775‡
70	0.201*‡	0.129	0.0722‡
80	0.213*‡	0.145	0.0676‡
90	0.224*	0.161	0.0631‡
100	0.235*	0.176	0.0592‡
150	0.293*	0.248	0.0451‡
200	0.347*	0.311	0.0364‡
250	0.399*	0.368	0.0306‡
273	0.422*	0.393	0.0286‡
300	0.446	0.420	0.0265‡
350	0.489*	0.466	0.0234‡
400	0.529*	0.508	0.0209‡
500	0.596*	0.579	0.0174‡
600	0.652*	0.637	0.0148‡
700	0.698*	0.685	0.0130‡
800	0.735*	0.723	0.0116‡
900	0.763*	0.753	0.0104‡
933	0.773*	0.763	0.0101‡

Al: 20.00% (37.06 At.%), Cu: 80.00% (62.94 At.%)

T	k	k_e	k_g
4			0.00440‡
6			0.00991‡
8			0.0169‡
10			0.0251‡
15			0.0464‡
20			0.0650‡
25			0.0709‡
30			0.0851‡
40			0.0891‡
50			0.0852‡
60			0.0801‡
70			0.0748‡
80			0.0699‡
90			0.0653‡
100			0.0613‡
150			0.0467‡
200			0.0377‡
250			0.0317‡
273			0.0296‡
300	0.278*‡	0.250‡	0.0275‡
350			0.0243‡
400			0.0217‡
500			0.0180‡
600			0.0154‡
700			0.0135‡
800			0.0120‡
900			0.0108‡
1000			0.00980‡
1100			0.00902‡
1224			0.00821‡

Al: 15.00% (29.36 At.%), Cu: 85.00% (70.64 At.%)

T	k	k_e	k_g
4			0.00471‡
6			0.0107‡
8			0.0182‡
10			0.0269‡
15			0.0498‡
20			0.0696‡
25			0.0634‡
30			0.0913‡
40			0.0954‡
50			0.0917‡
60			0.0860‡
70			0.0801‡
80			0.0749‡
90			0.0700‡
100			0.0658‡
150			0.0501‡
200			0.0404‡
250			0.0340‡
273			0.0318‡
300	0.442‡	0.412	0.0295‡
350	0.477‡	0.451	0.0260‡
400	0.507‡	0.484	0.0233‡
500	0.556‡	0.537	0.0193‡
600	0.593*‡	0.576	0.0166‡
700	0.620*‡	0.606	0.0144‡
800	0.642*‡	0.629	0.0128‡
900	0.659*‡	0.647	0.0116‡
1000	0.671*‡	0.660	0.0106‡
1200	0.686*‡	0.677	0.00896‡
1308	0.691*‡	0.683	0.00832‡

† Uncertainties of the total thermal conductivity, k, are as follows:
30.00 Al - 70.00 Cu: ±25% below 80 K, ±10% between 80 and 200 K, and ±8% above 200 K.
25.00 Al - 75.00 Cu: ±30% below 80 K, ±10% between 80 and 200 K, and ±8% above 200 K.
20.00 Al - 80.00 Cu: ±20% at 300 K.
15.00 Al - 85.00 Cu: ±20% above 300 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 2. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Al: 10.00% (20.77 At.%) Cu: 90.00% (79.23 At.%)				Al: 5.00% (11.03 At.%) Cu: 95.00% (88.97 At.%)				Al: 3.00% (6.79 At.%) Cu: 97.00% (93.21 At.%)				Al: 1.00% (2.32 At.%) Cu: 99.00% (97.68 At.%)			
				ρ_o = 7.23 μΩcm				ρ_o = 5.53 μΩcm				ρ_o = 2.36 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4			0.00522§	4	0.0197	0.0134	0.00628‡	4	0.0259	0.0177	0.00816‡	4	0.0531	0.0412	0.0119‡
6			0.0118§	6	0.0345	0.0204	0.0141‡	6	0.0450	0.0265	0.0185‡	6	0.0865	[illegible]	0.0267‡
8			0.0201§	8	0.0509	0.0268	0.0241‡	8	0.0669	0.0352	0.0317‡	88	0.129	0.0824	0.0466‡
10			0.0299§	10	0.0694	0.0336	0.0358‡	10	0.0896	0.0441	0.0455‡	10	0.173	0.103	0.0700‡
15			0.0551§	15	0.116	0.0495	0.0662‡	15	0.151	0.0654	0.0856‡	15	0.284	0.153	0.131‡
20			0.0772§	20	0.159	0.0665	0.0922‡	20	0.207	0.0867	0.120‡	20	0.382	0.201	0.181‡
25			0.0924§	25	0.193	0.0824	0.111‡	25	0.249	0.106	0.143‡	25	0.463	0.250	0.213‡
30			0.101§	30	0.220	0.0984	0.122‡	30	0.282	0.128	0.157‡	30	0.528	0.298	0.230‡
40			0.106§	40	0.257	0.130	0.127‡	40	0.329	0.169	0.160‡	40	0.619	0.389	0.230‡
50			0.102§	50	0.283	0.161	0.122‡	50	0.361	0.209	0.152‡	50	0.687	0.474	0.213‡
60			0.0962§	60	0.304	0.189	0.115‡	60	0.388	0.246	0.142‡	60	0.746	0.551	0.195‡
70			0.0890§	70	0.324	0.217	0.107‡	70	0.414	0.283	0.131‡	70	0.796	0.618	0.178‡
80			0.0831§	80	0.344*	0.244	0.0995‡	80	0.440*	0.318	0.122‡	80	0.852*	0.688	0.164‡
90			0.0778§	90	0.364*	0.271	0.0931‡	90	0.465*	0.352	0.113‡	90	0.902*	0.751	0.151‡
100			0.0730§	100	0.385*	0.298	0.0873‡	100	0.491*	0.386	0.105‡	100	0.953*	0.813	0.140‡
150			0.0555§	150	0.486*	0.420	0.0665§	150	0.618*	0.540	0.0782§	150	1.18*	1.08	0.103§
200	0.442*	0.397	0.0448§	200	0.581*	0.527	0.0538§	200	0.740*	0.677	0.0626§	200	1.38*	1.30	0.0816§
250	0.522*	0.484	0.0377§	250	0.673*	0.628	0.0452§	250	0.854*	0.802	0.0525§	250	1.55*	1.48	0.0678§
273	0.555*	0.520	0.0352§	273	0.713*	0.671	0.0422§	273	0.903*	0.854	0.0489§	273	1.63*	1.57	0.0628§
300	0.586	0.563	0.0227§	300	0.757	0.718	0.0391§	300	0.960	0.915	0.0452§	300	1.71	1.65	0.0580§
350	0.665	0.636	0.0288§	350	0.835	0.800	0.0346§	350	1.06	1.02	0.0398§	350	1.83	1.78	0.0506§
400	0.730	0.704	0.0258§	400	0.905	0.874	0.0309§	400	1.15	1.11	0.0356§	400	1.94	1.89	0.0450§
500	0.843	0.822	0.0214§	500	1.03	1.00	0.0257§	500	1.30	1.27	0.0294§	500	2.10	2.06	0.0369§
600	0.941	0.923	0.0183§	600	1.13	1.11	0.0220§	600	1.43*	1.40	0.0251§	600	2.22*	2.19	0.0310§
700	1.03	1.01	0.0190§	700	1.22	1.20	0.0192§	700	1.51*	1.49	0.0219§	700	2.31*	2.28	0.0269§
800	1.09	1.08	0.0143§	800	1.30	1.28	0.0171§	800	1.59*	1.57	0.0195§	800	2.37*	2.35	0.0236§
900	1.14	1.13	0.0123§	900	1.36	1.34	0.0154§	900	1.66*	1.64	0.0175§	900	2.41*	2.39	0.0211§
1000	1.18	1.17	0.0117§	1000	1.39	1.38	0.0140§	1000	1.70*	1.68	0.0158§	1000	2.44*	2.42	0.0190§
1200	1.25	1.24	0.00991§	1200	1.47*	1.46	0.0119§	1200	1.77*	1.76	0.0135§	1200	2.48*	2.46	0.0159§
1313	1.27	1.26	0.00918§	1331	1.50*	1.49	0.0108§	1331	1.80*	1.79	0.0123§	1351	2.49*	2.48	0.0142§

† Uncertainties of the total thermal conductivity, k, are as follows:

10.00 Al - 90.00 Cu: ±10% above 200 K.
5.00 Al - 95.00 Cu: ±8% below 80 K, ±6% between 80 and 500 K, and ±8% above 500 K.
3.00 Al - 97.00 Cu: ±8% below 80 K, ±5% between 80 and 500 K, and ±7% above 500 K.
1.00 Al - 99.00 Cu: ±8% below 80 K, ±5% between 80 and 500 K, and ±6% above 500 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 2. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM (continued)†

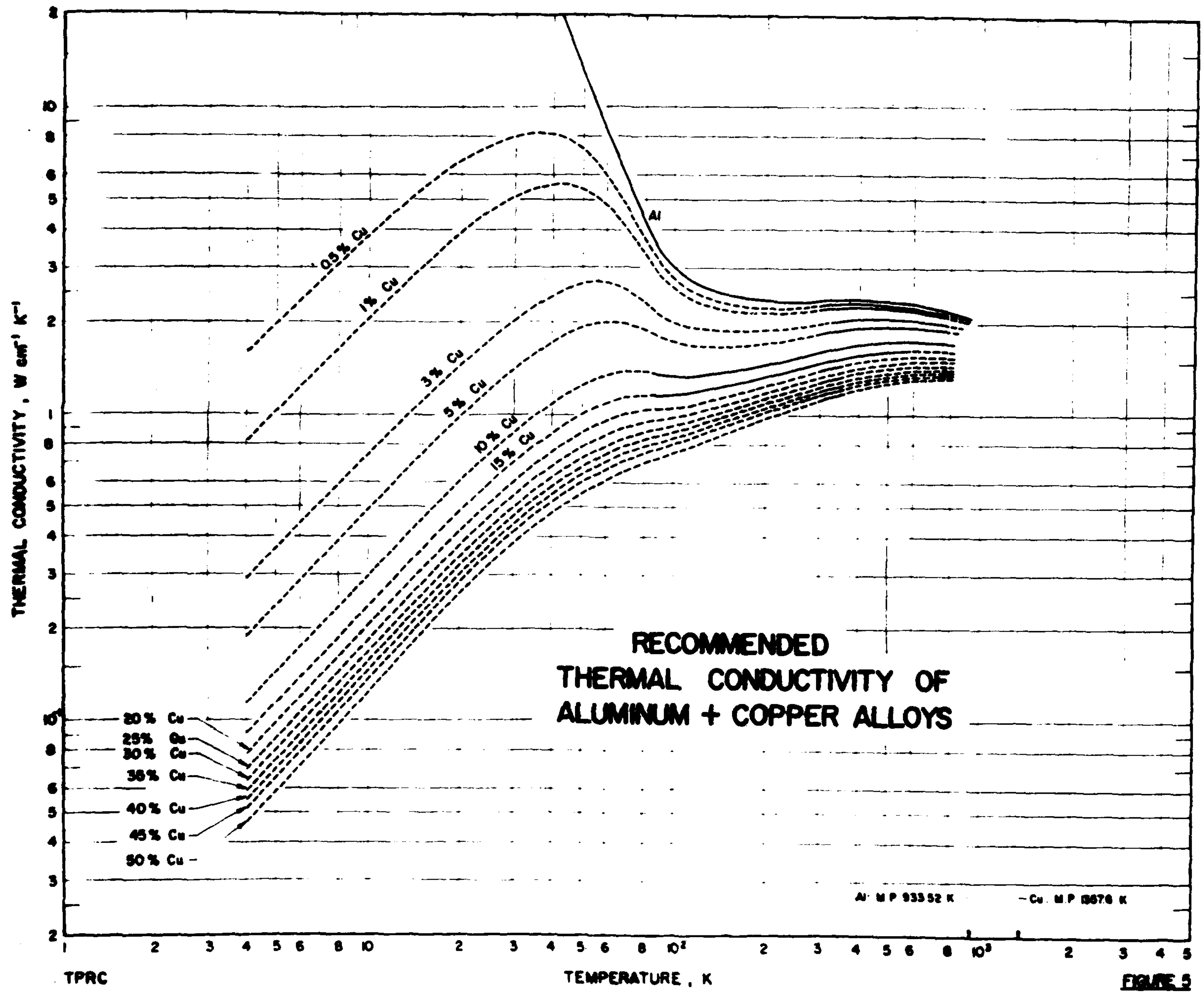
[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Al: 0.50% (1.17 At.%) Cu: 99.50% (98.83 At.%)						
ρ_0 = 1.270 μΩcm						
T	k	k_e	k_g			
4	0.0911	0.0771	0.0140			
6	0.146	0.115	0.0314			
8	0.209	0.154	0.0552			
10	0.277	0.192	0.0854			
15	0.445	0.282	0.163			
20	0.591	0.369	0.222			
25	0.715	0.455	0.260			
30	0.819	0.530	0.289			
40	0.975	0.696	0.280			
50	1.09	0.832	0.260			
60	1.18	0.948	0.236			
70	1.26	1.05	0.214			
80	1.34*	1.15	0.196			
90	1.40*	1.22	0.180			
100	1.47*	1.30	0.166			
150	1.74*	1.62	0.121‡			
200	1.96*	1.87	0.0950‡			
250	2.14*	2.06	0.0786‡			
273	2.21*	2.14	0.0731‡			
300	2.28	2.21	0.0672‡			
350	2.39	2.33	0.0585‡			
400	2.49	2.44	0.0520‡			
500	2.63*	2.59	0.0422‡			
600	2.73*	2.69	0.0355‡			
700	2.76*	2.73	0.0306‡			
800	2.79*	2.76	0.0268‡			
900	2.80*	2.78	0.0238‡			
1000	2.80*	2.78	0.0215‡			
1200	2.79*	2.77	0.0180‡			
1364	2.76*	2.74	0.0160‡			

† Uncertainties of the total thermal conductivity, k, are as follows:
0.50 Al - 99.50 Cu: ±6% below 80 K, ±5% between 80 and 500 K, and ±6% above 500 K.

‡ Typical value.

* In temperature range where no experimental thermal conductivity data are available.



TPRC

FIGURE 5

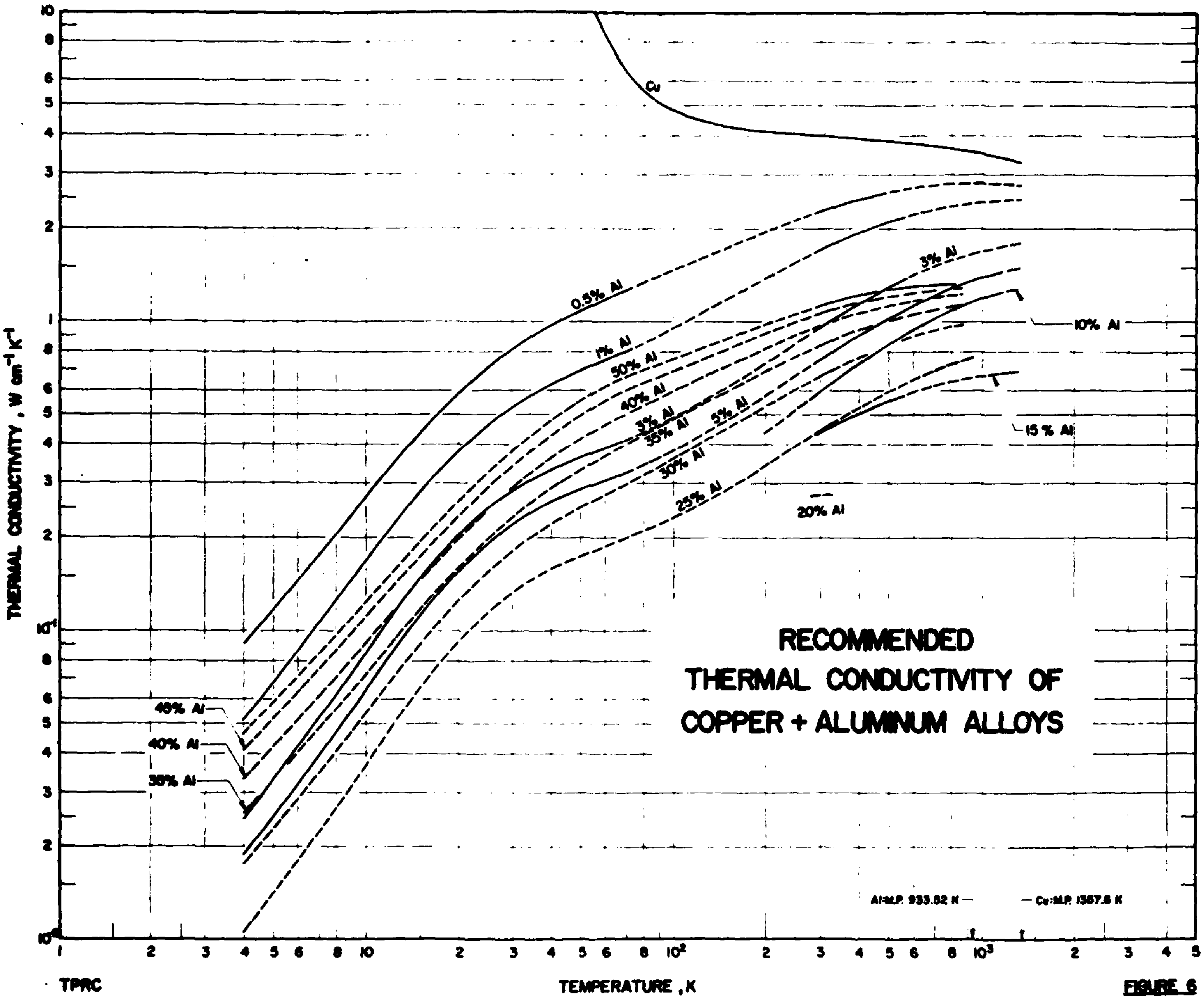

RECOMMENDED
THERMAL CONDUCTIVITY OF
COPPER + ALUMINUM ALLOYS
THERMAL CONDUCTIVITY, W cm^{-1} K^{-1}
TEMPERATURE, K
Cu
0.5% Al
1% Al
3% Al
5% Al
10% Al
15 % Al
20% Al
25% Al
30% Al
35% Al
40% Al
45% Al
50% Al
Al:M.P. 933.52 K
Cu:M.P. 1357.6 K
TPRC

FIGURE 6

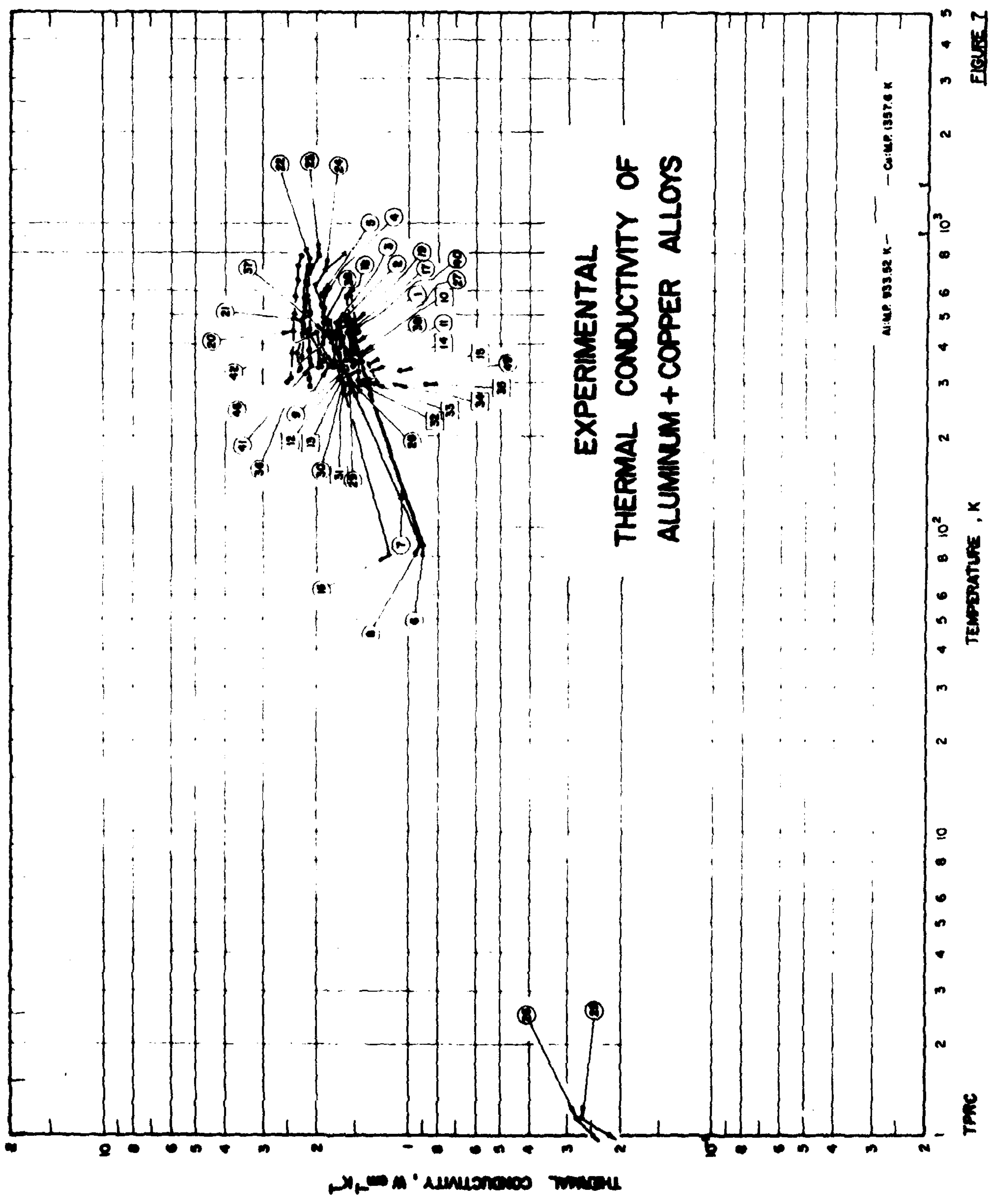

EXPERIMENTAL
THERMAL CONDUCTIVITY OF
ALUMINUM + COPPER ALLOYS
TEMPERATURE, K
THERMAL CONDUCTIVITY, W cm^{-1} K^{-1}
TPRC
Al: M.P. 933.52 K
Cu: M.P. 1357.6 K

FIGURE 7

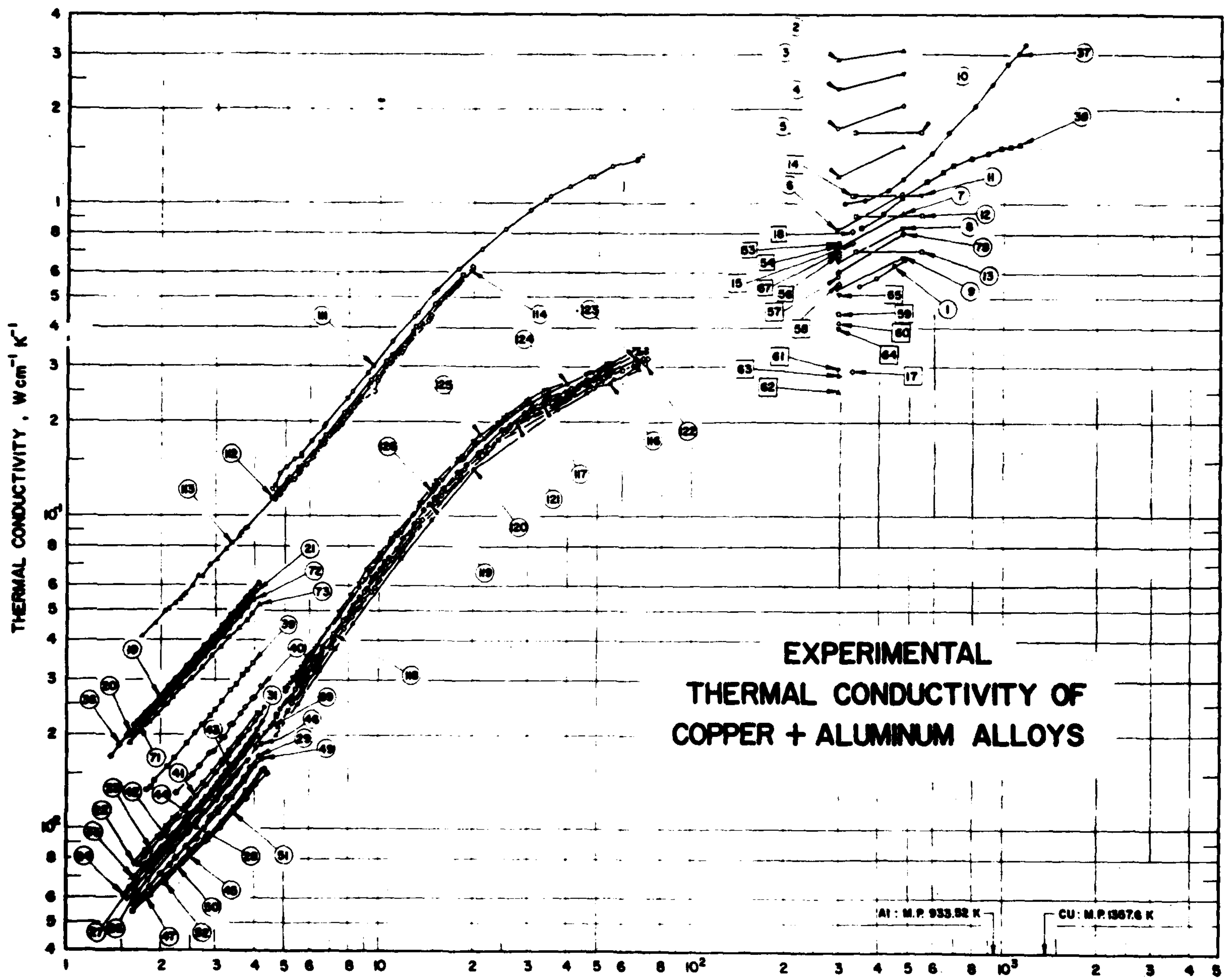

EXPERIMENTAL
THERMAL CONDUCTIVITY OF
COPPER + ALUMINUM ALLOYS
THERMAL CONDUCTIVITY , W cm⁻¹ K⁻¹
TEMPERATURE , K
Al : M.P. 933.52 K
CU : M.P. 1357.6 K
TPRC

FIGURE 8

TABLE 3. THERMAL CONDUCTIVITY OF ALUMINUM + COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Cu	Composition (continued), Specifications, and Remarks
1	44	Griffiths, E. and Schofield, F.H.	1928	L	353-473	No. 655	86.0	14.0	1.125 in. diameter and 15.5 in. long; 2 specimens chill-cast and 2 specimens sand-cast; one of each annealed at 450 C for 1 hr; electrical resistivity reported as 5.24, 6.25, 6.97, 7.69, 8.40, and 9.14 $\mu\Omega$ cm at 353, 423, 473, 523, 573, and 623 K, respectively; smoothed values reported.
2	44	Griffiths, E. and Schofield, F.H.	1928	L	353-473	No. 671	88.0	12.0	Similar to above except electrical resistivity reported as 5.20, 5.96, 6.51, 7.03, 7.57, and 8.11 $\mu\Omega$ cm at 353, 423, 473, 523, 573, and 623 K, respectively.
3	44	Griffiths, E. and Schofield, F.H.	1928	L	353-473	No. 921	~88.0	~12.0	Trace Fe; 1.125 in. diameter and 15.5 in. long; 2 specimens chill-cast; one of which annealed at 450 C for 1 hr; electrical resistivity reported as 4.64, 5.61, 6.34, 7.12, 7.95, and 8.92 $\mu\Omega$ cm at 353, 423, 473, 523, 573, and 623 K, respectively; smoothed values reported.
4	44	Griffiths, E. and Schofield, F.H.	1928	L	353-573	No. 2313	92.0	8.0	Similar to above except electrical resistivity reported as 4.06, 4.77, 5.40, 6.16, 7.03, and 8.08 $\mu\Omega$ cm at 353, 423, 473, 523, 573, and 623 K, respectively.
5	44	Griffiths, E. and Schofield, F.H.	1928	L	353-573	No. 2312	95.5	4.5	Similar to above except electrical resistivity reported as 4.04, 4.96, 5.61, 6.26, 6.92, and 7.58 $\mu\Omega$ cm at 353, 423, 473, 523, 573, and 623 K, respectively.
6	41	Mannchen, W.	1931	L	87-476		92.0	8.0	Cast; electrical conductivity reported as 65.1, 29.3, 20.2, and 14.6 x 10^4 Ω^{-1} cm^{-1} at 87, 273, 373, and 476 K, respectively; Lorenz function 1.549, 1.650, 1.891, and 2.18 x 10^{-8} V^2 K^{-2} at the above temperatures, respectively.
7*	41	Mannchen, W.	1931	L	87-476				The above specimen; Lorenz function 1.58, 1.64, 1.94, and 2.20 x 10^{-8} V^2 K^{-2} at the above temperatures, respectively.
8	41	Mannchen, W.	1931	L	87-476		85.0	15.0	Cast; electrical conductivity reported as 59.6, 22.3, 16.0, and 14.2 x 10^4 Ω^{-1} cm^{-1} at 87, 273, 373, and 476 K, respectively; Lorenz function 1.74, 2.43, 2.79, and 2.67 x 10^{-8} V^2 K^{-2} at the above temperatures, respectively.
9	113	Grard, C. and Villey, J.	1927	E	353-423		96.0	4.0	Approximate composition; cast.
10	113	Grard, C. and Villey, J.	1927	E	373.2		88.0	12.0	Cast; density 2.95 g cm^{-3}; electrical conductivity 0.16 x 10^6 Ω^{-1} cm^{-1} at 100 C.
11	114	Czochralski, J.	1921		301-346		92.0	~8.0	Trace Si; density 2.86 to 2.9 g cm^{-3}.
12	45	Smith, A.W.	1925	L	326.2		90.0	10.0	1.9 cm in diameter and 10 cm long; prepared by fusing 99.97+ pure aluminum and copper supplied by Baker; electrical conductivity 26.0 x 10^4 Ω^{-1} cm^{-1} at 23 C.
13	45	Smith, A.W.	1925	L	326.2		80.0	20.0	Similar to above except electrical conductivity 20.9 x 10^4 Ω^{-1} cm^{-1} at 23 C.
14	45	Smith, A.W.	1925	L	326.2		70.0	30.0	Similar to above except electrical conductivity 18.5 x 10^4 Ω^{-1} cm^{-1} at 23 C.
15	45	Smith, A.W.	1925	L	326.2		50.0	50.0	Similar to above except electrical conductivity 15.3 x 10^4 Ω^{-1} cm^{-1} at 23 C.
16	42	Eucken, A. and Warrentrup, H.	1935	R	81, 273		96.0	4.0	Cast sheet; annealed at 510 C for 45 min and quenched in ice water; electrical resistivity 1.409 and 3.600 $\mu\Omega$ cm at -192 and 0 C, respectively.

* Not shown in figure.

TABLE 3. THERMAL CONDUCTIVITY OF ALUMINUM - COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Cu	Composition (continued), Specifications, and Remarks
17	46	Griffiths, E. and Shakespear, G.A.	1922	L	353-453	V 671 A	85.0	12.0	15 in. long and 1 in. in diameter; supplied by Metallurgical Dept. of National Physical Laboratory (England); chill-cast.
18	46	Griffiths, E. and Shakespear, G.A.	1922	L	373-573	V 671 D	88.0	12.0	Prepared from commercially pure aluminum; 15 in. long and 1 in. in diameter; supplied by Metallurgical Dept. of National Physical Lab.; annealed at 450 C.
19	46	Griffiths, E. and Shakespear, G.A.	1922	L	373-573	V 671 C	88.0	12.0	Similar to above specimen except sand-cast.
20	58	Mikryukov, V.E. and Karagezyan, A.G.	1961	E	288-777		99.5	0.5	3 mm diameter and 300 mm long; prepared from 99.9 pure Al.
21	58	Mikryukov, V.E. and Karagezyan, A.G.	1961	E	328-723		99.0	1.0	Similar to above.
22	58	Mikryukov, V.E. and Karagezyan, A.G.	1961	E	333-762		96.0	4.0	Similar to above.
23	58	Mikryukov, V.E. and Karagezyan, A.G.	1961	E	288-781		93.0	7.0	Similar to above.
24	58	Mikryukov, V.E. and Karagezyan, A.G.	1961	E	334-792		90.0	10.0	Similar to above.
25	43	Satterthwaite, C.B.	1962	L	0.4-1.2	Al-26		0.3	Bar specimen with end sections machined to 0.5 in. diameter and 0.375 in. long, and with center portion 3.2 cm long milled to 0.5 mm thick and 2 mm wide; electrical resistivity ratio $\rho(273K)/\rho(1.2K) = 28$; transition temperature (s.c.) $T_c = 1.149$ K; in superconducting state.
26	43	Satterthwaite, C.B.	1962	L	0.4-1.2	Al-26			The above specimen measured in normal state; reported values calculated from the given formula $k = 0.242\ T$ (W cm^{-1} K^{-1}) in the same temperature range as above.
27	115	Elflein, M.	1937	L	298-398	I, 1		5	Cylindrical specimen 1.5 cm in diameter and 3.0 cm in length; cast from 98 to 99 pure Al bar (contamination: <1.0 Fe, <0.9 Si, and <0.1 Cu + Zn) and key alloy (50 Al and 50 Cu) at 750 C, and then cooled in air; electrical resistivity reported as 5.00 $\mu\Omega$ cm at 20 C.
28	115	Elflein, M.	1937	L	298-398	I, 5		5	Similar to the above specimen except 99.5 pure Al notch bar (contamination: 0.28 Fe and 0.22 Si) used for the melting; electrical resistivity reported as 4.56 $\mu\Omega$ cm at 20 C.
29	115	Elflein, M.	1937	L	298-398	I, 5A		5	Similar to the above specimen except electrical resistivity reported as 4.66 $\mu\Omega$ cm at 20 C.
30	115	Elflein, M.	1937	L	298-398	I, 5B		5	Similar to the above specimen except electrical resistivity reported as 4.42 $\mu\Omega$ cm at 20 C.
31	116, 168	Aliev, N.A.	1953	L	295.2	1		10.24	1.25 cm^2 in cross-section and 0.84 cm thick; electrical conductivity 21.18 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.564 x 10^{-8} V^2 K^{-2}.
32	116, 168	Aliev, N.A.	1953	L	295.2	2		20.78	1.25 cm^2 in cross-section and 0.79 cm thick; electrical conductivity 18.79 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.594 x 10^{-8} V^2 K^{-2}.
33	116, 168	Aliev, N.A.	1953	L	295.2	3		30.32	1.25 cm^2 in cross-section and 0.90 cm thick; electrical conductivity 16.72 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.682 x 10^{-8} V^2 K^{-2}.

TABLE 3. THERMAL CONDUCTIVITY OF ALUMINUM - COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Cu	Composition (continued), Specifications, and Remarks
34	116, 168	Aliev, N.A.	1953	L	295.2	4		40.82	1.25 cm² in cross-section and 0.68 cm thick; electrical conductivity $15.26 \times 10^4\ \Omega^{-1}\ cm^{-1}$; total Lorenz function $2.455 \times 10^{-8}\ V^2\ K^{-2}$.
35	116, 168	Aliev, N.A.	1953	L	295.2	5		48.00	1.25 cm² in cross-section and 0.70 cm thick; electrical conductivity $12.41 \times 10^4\ \Omega^{-1}\ cm^{-1}$; total Lorenz function $2.378 \times 10^{-8}\ V^2\ K^{-2}$.
36	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	3	98.47	1.01	0.209 Fe; original composition reported as 98.99 Al (containing 0.21 Fe and 0.29 Si) and 0.287 Si; as cast.
37	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	5	94.47	5.06	0.199 Fe; original composition reported as 94.94 Al (containing 0.21 Fe and 0.29 Si) and 0.275 Si; as cast.
38	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	6	92.34	7.20	0.195 Fe; original composition reported as 92.80 Al (containing 0.21 Fe and 0.29 Si) and 0.269 Si; as cast.
39	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	8	88.05	11.51	0.186 Fe; original composition reported as 88.49 Al (containing 0.21 Fe and 0.29 Si) and 0.257 Si; as cast.
40	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	9	79.52	15.46	0.78 Fe; original composition reported as 84.54 Al (containing 0.21 Fe and 0.29 Si) and 0.245 Si; as cast.
41	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	3A	98.49	1.01	0.209 Fe; original composition reported as 98.49 Al (containing 0.21 Fe and 0.29 Si) and 0.287 Si; as cast.
42	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	5A	94.47	5.06	0.199 Fe; original composition reported as 94.94 Al (containing 0.21 Fe and 0.29 Si) and 0.275 Si; annealed at 500 C for 24 hr, furnace cooled.
43*	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	6A	92.34	7.20	0.195 Fe; original composition reported as 92.80 Al (containing 0.21 Fe and 0.29 Si) and 0.269 Si; annealed at 500 C for 24 hr, furnace cooled.
44*	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	8A	88.05	11.51	0.186 Fe; original composition reported as 86.49 Al (containing 0.21 Fe and 0.29 Si) and 0.257 Si; annealed at 500 C for 24 hr, furnace cooled.
45*	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	9A	84.12	15.46	0.178 Fe; original composition reported as 84.54 Al (containing 0.21 Fe and 0.29 Si) and 0.245 Si; annealed at 500 C for 24 hr, furnace cooled.
46*	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	10A	79.52	20.08	0.166 Fe; original composition reported as 79.92 Al (containing 0.21 Fe and 0.29 Si) and 0.232 Si; annealed at 500 C for 24 hr, furnace cooled.
47*	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	11A	74.03	25.60	0.156 Fe; original composition reported as 74.40 Al (containing 0.21 Fe and 0.29 Si) and 0.216 Si; annealed at 500 C for 24 hr, furnace cooled.
48*	47	Hanson, D. and Rodgers, C.E.	1932	L	338, 438	12A	69.17	30.46	0.146 Fe; original composition reported as 69.54 Al (containing 0.21 Fe and 0.29 Si) and 0.202 Si; annealed at 500 C for 24 hr, furnace cooled.
49	47	Hanson, D. and Rodgers, C.E.	1932	L	303, 373	10	79.52	20.08	0.165 Fe; original composition reported as 79.92 Al (containing 0.21 Fe and 0.29 Si) and 0.232 Si; as cast.

* Not shown in figure.

TABLE 4. THERMAL CONDUCTIVITY OF COPPER - ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
1	44	Griffiths, E. and Schofield, F.H.	1928	L	343-450	Aluminum bronze; 6	90.0	10.0	2.53 cm in diameter and 38 cm long; chill-cast and annealed; electrical resistivity reported as 14.7, 15.6, 16.0, 16.7, 17.5, and 18.3 $\mu\Omega$ cm at 293, 348, 373, 423, 473, and 523 K, respectively.
2	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	100	99.77	0.22	0.01 Fe; 0.75 in. in diameter and 8 in. long; rolled, annealed, and cold-drawn; heat-treated at 750 C for 2 hr; electrical conductivity reported as 41.91 and 27.59 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
3	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	101	99.47	0.47	0.02 Fe; similar to the above specimen except electrical conductivity reported as 32.10 and 22.91 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
4	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	76	99.20	0.71	0.09 Fe; similar to the above specimen except heat-treated at 700 C; electrical conductivity reported as 23.40 and 17.95 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
5	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	77	98.08	1.89	0.03 Fe; similar to the above specimen except electrical conductivity reported as 15.91 and 13.00 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
6	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	45	95.25	4.61	0.14 Fe; similar to the above specimen except electrical conductivity reported as 10.26 and 8.824 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
7	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	46	92.15	7.72	0.13 Fe; 0.75 in. in diameter and 8 in. long; rolled, annealed, and cold-drawn; *heat-treated at 750 C for 3.5 hr; slowly cooled in furnace*; electrical conductivity reported as 8.834 and 7.65 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
8	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	102	90.56	9.37	0.07 Fe; similar to the above specimen except heat-treated at 750 C for 2 hr, then very slowly cooled in furnace to 550 C, held for 4 hr, again furnace-cooled to 450 C, held for 16 hr, cooled to room temperature; electrical conductivity reported as 8.24 and 7.056 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
9	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	130	87.76	12.15	0.09 Fe; similar to the above specimen except electrical conductivity reported as 6.925 and 5.738 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
10	47	Hanson, D. and Rodgers, C.E.	1932	L	333,543	30a	98.25	1.75	Prepared from Al (containing 0.21 Fe, 0.29 Si) and high grade Cu; 0.5 in. diameter and 6.5 in. long; cast in iron mould 7 in. long and 9/16 in. in diameter, machined to size; annealed at 500 C.
11	47	Hanson, D. and Rodgers, C.E.	1932	L	333,543	28	94.90	5.10	Similar to the above specimen.
12	47	Hanson, D. and Rodgers, C.E.	1932	L	333,543	27a	91.55	8.45	Similar to the above specimen.
13	47	Hanson, D. and Rodgers, C.E.	1932	L	333,543	25	87.22	12.78	Similar to the above specimen.
14	45	Smith, A.W.	1925	L	326.2		50.0	50.0	1.9 cm in diameter and 10 cm long; prepared by double-fusing the Baker's analyzed copper and aluminum; electrical conductivity 15.3 x 10^4 Ω^{-1} cm^{-1} at 23 C.
15	45	Smith, A.W.	1925	L	326.2		60.0	40.0	Similar to the above specimen except electrical conductivity 10.6 x 10^4 Ω^{-1} cm^{-1} at 23 C.
16	45	Smith, A.W.	1925	L	326.2		70.0	30.0	Similar to the above specimen except electrical conductivity 9.76 x 10^4 Ω^{-1} cm^{-1} at 23 C.

TABLE 4. THERMAL CONDUCTIVITY OF COPPER + ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
17	45	Smith, A.W.	1925	L	326.2		80.0	20.0	Similar to the above specimen except electrical conductivity 3.60 x 10^4 Ω^{-1} cm^{-1} at 23 C.
18	45	Smith, A.W.	1925	L	326.2		90.0	10.0	Similar to the above specimen except electrical conductivity 9.98 x 10^4 Ω^{-1} cm^{-1} at 23 C.
19	51	Salter, J.A.M. and Charsley, P.	1967	L	1.7-4.2	2S	99.17	0.83	Calculated composition; single crystal; grown in a sealed graphite mould using the Bridgman technique; annealed in vacuo at 750 C for 14 hr; residual electrical resistivity 2.07 $\mu\Omega$ cm.
20	51	Salter, J.A.M. and Charsley, P.	1967	L	1.6-4.2	2	99.10	0.90	Calculated composition; polycrystalline; rod specimen 3 mm in diameter; annealed in vacuo at 750 C for 14 hr; residual electrical resistivity 2.12 $\mu\Omega$ cm; grain size 0.008 cm.
21	51	Salter, J.A.M. and Charsley, P.	1967	L	1.8-4.1	2AR	99.17	0.83	Calculated composition; polycrystalline; rod specimen 3 mm in diameter; residual electrical resistivity 2.10 $\mu\Omega$ cm; grain size 0.0015 cm.
22	51	Salter, J.A.M. and Charsley, P.	1967	L	1.7-4.2	8S	96.69	3.31	Calculated composition; single crystal; grown in a sealed graphite mould using the Bridgman technique; annealed in vacuo at 750 C for 14 hr; residual electrical resistivity 6.50 $\mu\Omega$ cm.
23	51	Salter, J.A.M. and Charsley, P.	1967	L	1.7-4.2	8	95.91	4.09	Calculated composition; polycrystalline; rod specimen 3 mm in diameter; annealed in vacuo at 750 C for 14 hr; grain size 0.0063 cm; residual electrical resistivity 6.63 $\mu\Omega$ cm.
24	51	Salter, J.A.M. and Charsley, P.	1967	L	1.5-4.2	12	94.89	5.11	Calculated composition; similar to the above specimen except residual electrical resistivity 7.21 $\mu\Omega$ cm and grain size 0.011 cm.
25*	51	Salter, J.A.M. and Charsley, P.	1967	L	1.9-4.1	12(550)	94.72	5.28	Calculated composition; polycrystalline; rod specimen 3 mm in diameter; annealed in vacuo at 550 C for 14 hr; grain size 0.0025 cm; residual electrical resistivity 7.41 $\mu\Omega$ cm.
26	51	Salter, J.A.M. and Charsley, P.	1967	L	1.7-4.0	12(450)	94.72	5.28	Calculated composition; polycrystalline; rod specimen 3 mm in diameter; annealed in vacuo at 450 C for 14 hr; residual electrical resistivity 7.57 $\mu\Omega$ cm; grain size 0.0009 cm.
27	117	Charsley, P., Leever, A.D.W. and Salter, J.A.M.	1968	L	1.7-4.1		94.87	5.13	Single crystal; 0.2 x 10 x 2.5 cm; prepared by International Research and Development Co.; grown in graphite mould using Bridgman technique; measured in jig in the relaxed condition.
28	117	Charsley, P., et al.	1968	L	1.8-4.1		94.87	5.13	The above specimen; measured in jig under a stress of 7 kg mm^{-2}.
29	117	Charsley, P., et al.	1968	L	1.7-4.2		94.87	5.13	Polycrystalline; prepared by International Research and Development Co.; measured in jig in the relaxed condition.
30*	117	Charsley, P., et al.	1968	L	1.7-4.1		94.87	5.13	The above specimen; annealed at 750 C for 15 hr and measured in jig under a stress of 7 kg mm^{-2}.
31	117	Charsley, P., et al.	1968	L	1.9-4.1	A_1A_2; cross 1	94.87	5.13	Single crystal; grown in graphite mould using Bridgman technique; prepared by International Research and Development Co.; cross shape specimen obtained by cutting perpendicular to the large face of the crystal (0.2 x 10 x 2.5 cm); the orientation of the cross was chosen such that the primary edge dislocations made equal angles with both arms A_1A_2 and B_1B_2, the angle between the screw dislocations and these two directions however differed; heat flow in the arm A_1A_2 direction (angle to edges 55°, and angle to screws 35°)

* Not shown in figure.

TABLE 4. THERMAL CONDUCTIVITY OF COPPER + ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
32*	117	Charsley, P., Leaver, A.D.W. and Salter, J.A.M.	1968	L	2.0-4.2	A_1A_2; cross 1	94.87	5.13	The above specimen measured in different cryostats.
33	117	Charsley, P., et al.	1968	L	1.7-4.1	B_1B_2; cross 1			The above specimen; heat flow in the arm B_1B_2 direction (angle to edges 63°, and angle to screws 73°).
34*	117	Charsley, P., et al.	1968	L	1.7-4.2	A_1A_2; cross 2	94.87	5.13	Similar to the above specimen except the orientation of the cross was chosen such that the primary edge dislocations made different angles with both arms A_1A_2 and B_1B_2, the angle between the screw dislocations and these two directions however equal; heat flow in the arm A_1A_2 direction (angle to edges 80°, and angle to screws 52°).
35*	117	Charsley, P., et al.	1968	L	1.8-3.4	B_1B_2; cross 2			The above specimen; heat flow in the arm B_1B_2 direction (angle to edges 46°, and angle to screws 52°).
36	19	Lindenfeld, P. and Pennebaker, W.B.	1962	L	1.4-4.2			0.617	Calculated composition; 3 x 0.125 x 0.031 in.; prepared from 99.999 pure Cu and 99.99+ pure Al; materials melted, outgassed in vacuum, stirred for 0.5 hr, then cast; annealed at 700 C for 22 hr; residual electrical resistivity 2.10 μΩ cm.
37	58	Inouye, H.	1957	C	309-1171		94	6	Iron and alumina used as comparative materials; data taken from smoothed curve.
38	58	Inouye, H.	1957	C	348-1125		92	8	Similar to the above specimen.
39	118	Charsley, P. and Salter, J.A.M.	1965	L	1.8-4.0	4		1.84	Calculated composition; polycrystalline; 3 mm diameter and 12 cm long; prepared by International Research and Development Co., Ltd.; materials melted in pure argon, cast, machined, swaged, and drawn; annealed in vacuo at 750 C for 14 hr; residual electrical resistivity 3.88 μΩ cm.
40	118	Charsley, P. and Salter, J.A.M.	1965	L	2.3-4.2	6		2.68	Similar to the above specimen except residual electrical resistivity 5.20 μΩ cm.
41	118	Charsley, P. and Salter, J.A.M.	1965	L	2.0-4.4	10		4.22	Similar to the above specimen except residual electrical resistivity 6.62 μΩ cm.
42*	118	Charsley, P. and Salter, J.A.M.	1965	L	1.8-3.1	12S		5.11	Calculated composition; single crystal; 3 mm diameter and 12 cm long; grown by the Bridgman technique; grain size 0.1 ~ 0.3 mm; residual electrical resistivity 7.49 μΩ cm.
43	118	Charsley, P. and Salter, J.A.M.	1965	L	2.2-4.2	12S			The above specimen; 2nd run.
44	118	Charsley, P. and Salter, J.A.M.	1965	L	2.5-4.0	12S			Similar to the above specimen.
45	83	Kusunoki, M. and Suzuki, H.	1969	L	1.7-4.3	Specimen No. 5	93.03	6.97	Calculated composition; single crystal; cross-sectional area 2.846 mm^2; prepared from 99.999 pure Cu (Mitsubishi-Kinzoku Co. Ltd.) and 99.99 pure Al (Sumitomo-Kinzoku Co. Ltd.) by melting in a high purity graphite crucible by induction heating; grown in a splitting graphite mould by the Bridgman method using a seed crystal; annealed at 1000 C for 48 hr in a vacuum better than 10^{-5} mm Hg; electrolytically polished in phosphoric acid-ethyl alcohol; dislocation density 5.8 x 10^{6} cm^{-2}; residual electrical resistivity 7.617 μΩ cm.

* Not shown in figure.

TABLE 4. THERMAL CONDUCTIVITY OF COPPER - ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
46	53	Kusunoki, M. and Suzuki, H.	1969	L	1.7-4.3	Specimen No. 9	93.03	6.97	Similar to the above specimen except specimen cross-sectional area 2.924 mm^2, dislocation density 1.0 x 10^{6} cm^{-2}, and residual electrical resistivity 7.108 $\mu\Omega$ cm.
47	53	Kusunoki, M. and Suzuki, H.	1969	L	1.8-4.3	Specimen No. 11			Similar to the above specimen except specimen cross-sectional area 1.535 mm^2, dislocation density 6.6 x 10^{10} cm^{-2}, and residual electrical resistivity 7.568 $\mu\Omega$ cm.
48*	53	Kusunoki, M. and Suzuki, H.	1969	L	1.7-4.3	Specimen No. 12(1)			Similar to the above specimen except specimen cross-sectional area 1.915 mm^2, dislocation density 2.0 x 10^{10} cm^{-2}, and residual electrical resistivity 7.562 $\mu\Omega$ cm.
49	53	Kusunoki, M. and Suzuki, H.	1969	L	1.7-4.3	Specimen No. 13(1)			Similar to the above specimen except specimen cross-sectional area 2.318 mm^2, dislocation density 3.6 x 10^{9} cm^{-2}, and residual electrical resistivity 7.571 $\mu\Omega$ cm.
50	53	Kusunoki, M. and Suzuki, H.	1969	L	1.6-4.3	Specimen No. 13(2)			Similar to the above specimen except specimen cross-sectional area 2.055 mm^2, dislocation density 4.4 x 10^{10} cm^{-2}, and residual electrical resistivity 7.605 $\mu\Omega$ cm.
51	53	Kusunoki, M. and Suzuki, H.	1969	L	1.8-4.3	Specimen No. 14			Similar to the above specimen except specimen cross-sectional area 1.569 mm^2, dislocation density 8.4 x 10^{10} cm^{-2}, and residual electrical resistivity 7.641 $\mu\Omega$ cm.
52	53	Kusunoki, M. and Suzuki, H.	1969	L	1.7-4.4	Specimen No. 12(2)			Same fabrication method and heat-treatment as the above specimen except no other details reported.
53	116, 166	Aliev, N.A.	1963	L	295.2	6	50.45		1.25 cm^2 in cross-section and 0.50 cm thick; electrical conductivity 10.68 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.345 x 10^{-8} V^{2}K^{-2}.
54	116, 166	Aliev, N.A.	1963	L	295.2	7	53.00		1.25 cm^2 in cross-section and 0.96 cm thick; electrical conductivity 10.74 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.334 x 10^{-8} V^{2}K^{-2}.
55*	116, 166	Aliev, N.A.	1963	L	295.2	8	55.00		1.25 cm^2 in cross-section and 0.52 cm thick; electrical conductivity 10.82 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.348 x 10^{-8} V^{2}K^{-2}.
56	116, 166	Aliev, N.A.	1963	L	295.2	9	59.62		1.25 cm^2 in cross-section and 0.52 cm thick; electrical conductivity 9.98 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.994 x 10^{-8} V^{2}K^{-2}.
57	116, 166	Aliev, N.A.	1963	L	295.2	10	69.99		1.25 cm^2 in cross-section and 1.18 cm thick; electrical conductivity 8.65 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.233 x 10^{-8} V^{2}K^{-2}.
58	116, 166	Aliev, N.A.	1963	L	295.2	11	71.00		1.25 cm^2 in cross-section and 0.96 cm thick; electrical conductivity 7.75 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.438 x 10^{-8} V^{2}K^{-2}.
59	116, 166	Aliev, N.A.	1963	L	295.2	12	73.00		1.25 cm^2 in cross-section and 1.49 cm thick; electrical conductivity 6.71 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.247 x 10^{-8} V^{2}K^{-2}.
60	116, 166	Aliev, N.A.	1963	L	295.2	13	76.00		1.25 cm^2 in cross-section and 0.80 cm thick; electrical conductivity 6.02 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.438 x 10^{-8} V^{2}K^{-2}.
61	116, 166	Aliev, N.A.	1963	L	295.2	14	77.00		1.25 cm^2 in cross-section and 0.74 cm thick; electrical conductivity 4.25 x 10^4 Ω^{-1} m^{-1}; total Lorenz function 2.438 x 10^{-8} V^{2}K^{-2}.
62	116, 166	Aliev, N.A.	1963	L	295.2	15	78.00		1.25 cm^2 in cross-section and 0.80 cm thick; electrical conductivity 3.54 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.392 x 10^{-8} V^{2}K^{-2}.

* Not shown in figure.

TABLE 4. THERMAL CONDUCTIVITY OF COPPER + ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
63	116, 168	Aliev, N.A.	1953	L	295.2	16	79.58		1.25 cm^2 in cross-section and 0.95 cm thick; electrical conductivity 4.16 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.360 x 10^{-8} V^2K^{-2}.
64	116, 168	Aliev, N.A.	1953	L	295.2	17	83.00		1.25 cm^2 in cross-section and 1.16 cm thick; electrical conductivity 5.95 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.277 x 10^{-8} V^2K^{-2}.
65	116, 168	Aliev, N.A.	1953	L	295.2	18	88.00		1.25 cm^2 in cross-section and 1.35 cm thick; electrical conductivity 7.40 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.346 x 10^{-8} V^2K^{-2}.
66*	116, 168	Aliev, N.A.	1953	L	295.2	19	89.22		1.25 cm^2 in cross-section and 0.60 cm thick; electrical conductivity 10.04 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.304 x 10^{-8} V^2K^{-2}.
67	116, 168	Aliev, N.A.	1953	L	295.2	20	95.00		1.25 cm^2 in cross-section and 0.51 cm thick; electrical conductivity 10.50 x 10^4 Ω^{-1} cm^{-1}; total Lorenz function 2.258 x 10^{-8} V^2K^{-2}.
68*	180	Charsley, P. and Salter, J.A.M.	1965	L	1.6-4.1			5.47	Polycrystalline specimen; annealed.
69	180	Charsley, P. and Salter, J.A.M.	1965	L	1.6-4.5			5.47	Polycrystalline specimen; plastically deformed (6%).
70*	180	Charsley, P. and Salter, J.A.M.	1965	L	2.4-4.2			5.47	Polycrystalline specimen; plastically deformed (12%).
71	52	Charsley, P., Salter, J.A.M. and Leaver, A.D.W.	1968	L	1.6-4.2	2		0.90	Polycrystalline; 3 mm in diameter and 10 cm long; prepared by International Research and Development Co., Ltd.; annealed at 750 C for 15 hr in graphite tubes in vacuo and furnace cooled.
72	52	Charsley, P., et al.	1968	L	1.6-4.0	2 (2.9%)		0.90	Similar to the above specimen except 2.9% deformed.
73	52	Charsley, P., et al.	1968	L	1.6-4.2	2 (10%)		0.83	Similar to the above specimen except 10% deformed.
74*	52	Charsley, P., et al.	1968	L	1.7-4.2	8 (6%)		4.09	Similar to the above specimen except 6% deformed.
75*	52	Charsley, P., et al.	1968	L	1.6-4.4	12 (6.2%)		5.11	Similar to the above specimen except 6.2% deformed.
76*	52	Charsley, P., et al.	1968	L	2.4-4.2	12 (12.8%)		5.28	Similar to the above specimen except 12.8% deformed.
77*	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 50	59.38	9.90	0.22 Fe; 0.75 in. diameter and 8 in. long; rolled to 1.25 in. in diameter, annealed at 700-750 C, cold-drawn to size; heat-treated at 750 C for 3.5 hr, slowly air-cooled; electrical conductivity 7.923 and 6.724 x 10^1 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
78	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 49	89.38	9.41	0.52 Fe, 0.38 Sn, 0.31 Ni, and trace Zn; 0.75 in. diameter and 8 in. long; same fabrication method as the above specimen; heat-treated at 750 C for 3.5 hr, very slowly cooled; electrical conductivity 7.314 and 6.364 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
79	119, 160	Friedman, A.J., Chu, T.K., Klemens, P.G., and Reynolds, C.A.	1972	L	1.7-4.0	A		4.07	Polycrystalline; form factor 37.50 cm^{-1}; prepared from 99.999 pure copper supplied by Johnsons and Matthey and from 99.99 pure aluminum supplied by Jarrell Ash Co. by melting in an evacuated quartz boat, casting into a quartz capillary and quenching in an ice bath; annealed in vacuo at 1273 K for 18 hr; average grain size 1 mm; residual electrical resistivity 7.51 $\mu\Omega$ cm.

* Not shown in figure.

TABLE 4. THERMAL CONDUCTIVITY OF COPPER + ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
80	119, 169	Friedman, A.J., Chu, T.K., Klemens, P.G., and Reynolds, C.A.	1972	L	1.5-3.8	A			The above specimen irradiated for 6 hr at 25 to 60 C at the Brookhaven National Laboratory BMRR facility for a total fast neutron (>1 MeV) dosage of 4 x 10^{17} n cm^{-2} and a total thermal dosage of 1 x 10^{15} n cm^{-2}; form factor 37.57 cm^{-1}; residual electrical resistivity 7.46 $\mu\Omega$ cm.
81	119, 169,170	Friedman, A.J., et al.	1972	L	1.7-3.8	B		4.07	Same fabrication method as the above specimen A; form factor 35.67 cm^{-1}; residual electrical resistivity 7.60 $\mu\Omega$ cm.
82	119, 169,170	Friedman, A.J., et al.	1972	L	1.3-3.7	B			The above specimen deformed in tension, 6.1%, at room temperature; form factor 47.4 cm^{-1}; residual electrical resistivity 7.89 $\mu\Omega$ cm.
83	119, 169	Friedman, A.J., et al.	1972	L	1.3-3.8	B			The above specimen annealed in vacuo at 573 K for 24 hr; form factor 47.0 cm^{-1}; residual electrical resistivity 7.90 $\mu\Omega$ cm.
84	119, 169	Friedman, A.J., et al.	1972	L	1.4-3.9	B			The above specimen irradiation treated same as the above specimen A for curve No. 78; form factor 46.9 cm^{-1}; residual electrical resistivity 7.83 $\mu\Omega$ cm.
85	119, 169	Friedman, A.J., et al.	1972	L	1.6-3.8	B			The above specimen annealed in vacuo at 573 K for 24 hr; form factor 46.6 cm^{-1}; residual electrical resistivity 7.95 $\mu\Omega$ cm.
86	54	Mitchell, M.A., Klemens, P.G., and Reynolds, C.A.	1971	L	1.3-4.1	A		4.5	Obtained from Materials Research Corp., Orangeburg, N.Y.; prepared from 99.999 pure Al and Cu by vacuum induction melting, then machining and swaging to 0.125 in. in diameter; cold-worked in liquid nitrogen, then kept at 293 K for 3 hr; residual electrical resistivity 7.996 $\mu\Omega$ cm.
87	54	Mitchell, M.A., et al.	1971	L	1.4-4.1	B			Similar to the above specimen A but annealed at 1193 K for 46 hr after cold-work; residual electrical resistivity 7.461 $\mu\Omega$ cm.
88	54	Mitchell, M.A., et al.	1971	L	1.3-4.2	C1			Similar to the above specimen A but annealed at 1123 K for 28 hr after cold-work, then given 9.5% torsional strain at 293 K, re-annealed at 300 K for 12 hr; residual electrical resistivity 7.468 $\mu\Omega$ cm.
89	54	Mitchell, M.A., et al.	1971	L	1.4-4.1	C2			The above specimen re-annealed at 373 K for 48 hr; residual electrical resistivity 7.450 $\mu\Omega$ cm.
90	54	Mitchell, M.A., et al.	1971	L	1.4-4.0	C3			The above specimen re-annealed at 693 K for 20 hr; residual electrical resistivity 7.463 $\mu\Omega$ cm.
91	54	Mitchell, M.A., et al.	1971	L	1.3-4.1	C4			The above specimen re-annealed at 713 K for 48 hr; residual electrical resistivity 7.404 $\mu\Omega$ cm.
92	54	Mitchell, M.A., et al.	1971	L	1.2-4.1	D			Same composition, supplier, and fabrication method as the above specimen A but swaged to 3/16 in. in diameter; annealed at 1205 K for 48 hr; residual electrical resistivity 7.350 $\mu\Omega$ cm.
93	54	Mitchell, M.A., et al.	1971	L	1.5-4.1	E1			Similar to the above specimen D but given, after annealing, 9.33% tensile strain at 77 K with maximum stress 28.5 kg mm^{-2} and strain rate 0.0093 s^{-1}; then re-annealed at 300 K for 12 hr; residual electrical resistivity 7.566 $\mu\Omega$ cm.
94	54	Mitchell, M.A., et al.	1971	L	1.3-4.1	E2			The above specimen re-annealed at 422 K for 48 hr; residual electrical resistivity 7.475 $\mu\Omega$ cm.
95	54	Mitchell, M.A., et al.	1971	L	1.4-4.1	E3			The above specimen re-annealed at 552 K for 48 hr; residual electrical resistivity 7.498 $\mu\Omega$ cm.

TABLE 4. THERMAL CONDUCTIVITY OF COPPER + ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
96	54	Mitchell, M.A., Klemens, P.G., and Reynolds, C.A.	1971	L	1.2-4.1	E4		4.5	The above specimen re-annealed at 673 K for 48 hr; residual electrical resistivity 7.542 μΩ cm.
97	54	Mitchell, M.A., et al.	1971	L	1.2-4.2	E5			The above specimen re-annealed at 797 K for 48 hr; residual electrical resistivity 7.456 μΩ cm.
98	54	Mitchell, M.A., et al.	1971	L	1.2-4.2	E6			The above specimen re-annealed at 920 K for 48 hr; residual electrical resistivity 7.453 μΩ cm.
99	54	Mitchell, M.A., et al.	1971	L	1.4-4.1	E7			The above specimen re-annealed at 1202 K for 48 hr; residual electrical resistivity 7.441 μΩ cm.
100	54	Mitchell, M.A., et al.	1971	L	1.3-4.2	F1			Similar to the above specimen E1 but annealed at 1202 K for 48 hr, then given 8.13% tensile strain at 77 K with maximum stress 29 kg mm^{-2} and strain rate 0.0081 s^{-1}, re-annealed at 360 K for 48 hr; residual electrical resistivity 7.567 μΩ cm.
101	54	Mitchell, M.A., et al.	1971	L	1.4-4.2	F2			The above specimen re-annealed at 564 K for 0.5 hr; residual electrical resistivity 7.536 μΩ cm.
102	54	Mitchell, M.A., et al.	1971	L	1.2-4.2	F3			The above specimen re-annealed at 565 K for 1.5 hr; residual electrical resistivity 7.536 μΩ cm.
103	54	Mitchell, M.A., et al.	1971	L	1.5-4.2	F4			The above specimen re-annealed at 567 K for 48 hr; residual electrical resistivity 7.498 μΩ cm.
104	54	Mitchell, M.A., et al.	1971	L	1.5-4.2	F5			The above specimen re-annealed at 570 K for 97 hr; residual electrical resistivity 7.498 μΩ cm.
105	54	Mitchell, M.A., et al.	1971	L	1.3-4.2	G1			Similar to the above specimen F1 but given, after annealing, 9.26% tensile strain at 77 K with maximum stress 25.1 kg mm^{-2} and strain rate 0.004 s^{-1}, re-annealed at 344 K for 48 hr; residual electrical resistivity 7.644 μΩ cm.
106	54	Mitchell, M.A., et al.	1971	L	1.2-4.2	G2			The above specimen re-annealed at 670 K for 0.5 hr; residual electrical resistivity 7.625 μΩ cm.
107	54	Mitchell, M.A., et al.	1971	L	1.2-4.2	G3			The above specimen re-annealed at 661 K for 1.5 hr; residual electrical resistivity 7.612 μΩ cm.
108	54	Mitchell, M.A., et al.	1971	L	1.2-4.1	G4			The above specimen re-annealed at 660 K for 48 hr; residual electrical resistivity 7.601 μΩ cm.
109	54	Mitchell, M.A., et al.	1971	L	1.2-4.2	G5			The above specimen re-annealed at 732 K for 48 hr; residual electrical resistivity 7.553 μΩ cm.
110	54	Mitchell, M.A., et al.	1971	L	1.2-4.1	G6			The above specimen re-annealed at 1308 K for 48 hr; residual electrical resistivity 7.576 μΩ cm.
111	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	4.6-69	C1		0.43	Supplied by American Anaconda Brass Co.; 0.5 in. diameter x 8 in. long with central 5 in. machined to 0.25 in. in diameter; annealed at 1273 K for 48 hr; electrical resistivity 1.066, 1.066, 1.302, and 2.070 μΩ cm at 1.1, 4.2, 77, and 273 K, respectively.
112	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	4.5-55	C2			The above specimen fatigued for 500 cycles with maximum load 6.4 kg mm^{-2}; electrical resistivity 1.071, 1.067, 1.301, and 2.664 μΩ cm at 1.1, 4.2, 77, and 273 K, respectively.

TABLE 4. THERMAL CONDUCTIVITY OF COPPER - ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
113	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	1.7-72	C3		0.43	The above specimen fatigued for 10^4 cycles with maximum load 6.4 kg mm^{-2}; electrical resistivity 1.069, 1.069, 1.304, and 2.663 $\mu\Omega$ cm at 1.1, 4.2, 77, and 273 K, respectively.
114	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	4.6-69	C5			Similar to the above specimen C1 but given a 5% plastic deform under uniaxial stress; electrical resistivity 1.066, 1.066, 1.294, and 2.660 $\mu\Omega$ cm at 1.1, 4.2, 77, and 273 K, respectively.
115	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	4.6-66	C6			The above specimen fatigued for 10^5 cycles with maximum load 6.4 kg mm^{-2}; electrical resistivity 1.064, 1.306, and 2.665 $\mu\Omega$cm at 4.2, 77, and 273 K, respectively.
116	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	4.6-66	B1		6.97	Same supplier and dimensions as the above specimen C1; annealed at 1237 K for 48 hr; electrical resistivity 7.868, 7.867, 8.253, and 10.19 $\mu\Omega$ cm at 1.1, 4.2, 77, and 273 K, respectively.
117	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	4.9-68	B2			The above specimen fatigued for 500 cycles with maximum load 8.3 kg mm^{-2}; electrical resistivity 7.850, 7.853, 8.250, and 10.16 $\mu\Omega$ cm at 1.1, 4.2, 77, and 273 K, respectively.
118	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	4.7-68	B3			The above specimen fatigued for 10^4 cycles; electrical resistivity 7.806, 7.806, 8.204, and 10.19 $\mu\Omega$ cm at 1.1, 4.2, 77, and 273 K, respectively.
119	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	5.4-68	B4			The above specimen fatigued for 10^5 cycles; electrical resistivity 7.813, 7.813, 8.217, and 10.14 $\mu\Omega$ cm at 1.1, 4.2, 77, and 273 K, respectively.
120	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	4.7-68	B5		6.97	Similar to the above specimen B1 but given a 5% plastic deform under uniaxial stress; electrical resistivity 7.889, 7.889, 8.288, and 10.16 $\mu\Omega$ cm at 1.1, 4.2, 77, and 273 K, respectively.
121	48, 171	Chu, T.K. and Lipschultz, F.P.	1972	L	4.8-65	B6			The above specimen fatigued for 2 x 10^5 cycles with maximum load 8.3 kg mm^{-2}; electrical resistivity 7.891, 8.273, and 10.21 $\mu\Omega$ cm at 4.2, 77, and 273 K, respectively.
122	50	Friedman, A.J.	1974	L	5.3-73	5		4.07	The same irradiated specimen B for curve No. 82; electrical resistivity 7.832, 7.832, 8.204, and 10.033 $\mu\Omega$ cm at 1.2, 4.2, 77, and 273 K, respectively.
123	50	Friedman, A.J.	1974	L	5.3-70	5			The above specimen re-annealed at 573 K for 24 hr; electrical resistivity 7.949, 7.949, 8.314, and 10.150 K at 1.2, 4.2, 77, and 273 K, respectively.
124	50	Friedman, A.J.	1974	L	5.3-68	6		4.07	Form factor 37.497 cm^{-1}; annealed in vacuum at 1273 K for 18 hr; electrical resistivity 7.513, 7.513, 7.867, and 9.630 $\mu\Omega$ cm at 1.2, 4.2, 77, and 273 K, respectively.
125	50	Friedman, A.J.	1974	L	5.0-72	6			The above specimen.
126	50	Friedman, A.J.	1974	L	5.0-67	6			The above specimen given the same irradiation treatment as the specimen B for curve No. 82; form factor 37.569 cm^{-1}; electrical resistivity 7.461, 7.461, 7.812, and 9.564 $\mu\Omega$ cm at 1.2, 4.2, 77, and 273 K, respectively.
127	120	Leaver, A.D.W. and Charsley, P.	1971	L	1.9-4.0	2 Al		0.83	Similar to the specimen for curve No. 73; annealed; residual electrical resistivity 2.080 $\mu\Omega$cm.
128	120	Leaver, A.D.W. and Charsley, P.	1971	L	1.5-4.1	2 Al			The above specimen tensile strained 8.2% under a stress of 16.93 kg mm^{-2}; residual electrical resistivity 2.109 $\mu\Omega$cm.
129	120	Leaver, A.D.W. and	1971	L	2.0-4.0	12 Al		5.56	Polycrystalline; obtained from International Research and Development Co., Ltd.; residual electrical resistivity 7.61 $\mu\Omega$cm.

TABLE 4. THERMAL CONDUCTIVITY OF COPPER + ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
130	120	Leaver, A.D.W. and Charsley, P.	1971	L	1.8-4.0	12 Al			The above specimen tensile strained 1.8% under a stress of 16.36 kg mm^{-2}; residual electrical resistivity 7.62 μΩ cm.
131	120	Leaver, A.D.W. and Charsley, P.	1971	L	2.0-4.2	12 Al		5.56	Single crystal; grown in a graphite mold by the Bridgman technique; annealed.
132	120	Leaver, A.D.W. and Charsley, P.	1971	L	2.2-4.1	12 Al			The above specimen tensile strained 7.3% under a stress of 3.03 kg mm^{-2}.
133	120	Leaver, A.D.W. and Charsley, P.	1971	L	1.9-4.0	12 Al			The above specimen tensile strained 17.0% under a stress of 4.48 kg mm^{-2}.
134	120	Leaver, A.D.W. and Charsley, P.	1971	L	2.0-4.1	12 Al			The above specimen tensile strained 22.5% under a stress of 6.73 kg mm^{-2}.
135	121	Kogure, Y. and Hiki, Y.	1973	L	1.6-6.6		97.8	2.2	Calculated composition (5 a/o Al); 2.5 mm dia x 70 mm long; prepared from 99.99+ Cu and Al by vacuum melting and casting; annealed in vacuum at 850 C for 15 hrs.
136*	172	Kapoor, A., Rowlands, J.A., and Woods, S.B.	1974	L	0.48-3.9		95.5	4.5	Calculated composition (10 a/o Al); cylindrical specimen 3.6 mm in diameter; prepared by melting the pure materials in a quartz container in vacuum, resulted ingot swaged to size; cold-worked; residual electrical resistivity 7.54 μΩ cm.
137*	172	Kapoor, A., et al.	1974	L	0.52-4.0				The above specimen annealed in vacuum at 600 K for 12 hr; residual electrical resistivity 6.79 μΩ cm.
138*	172	Kapoor, A., et al.	1974	L	0.48-3.7				The above specimen reannealed in vacuum at 675 K for 12 hr; residual electrical resistivity 6.88 μΩ cm.
139*	172	Kapoor, A., et al.	1974	L	0.65-4.0				The above specimen reannealed in vacuum at 1000 K for 12 hr; residual electrical resistivity 6.69 μΩ cm.

* Not shown in figure.

4.2. Aluminum-Magnesium Alloy System

The aluminum-magnesium alloy system does not form a continuous series of solid solutions. The maximum solid solubility of magnesium in aluminum is 17.4% (18.9 At.%) at 723 K and the solubility decreases at higher and lower temperatures, being only 1.9% (2.1 At.%) at 373 K. The maximum solid solubility of aluminum in magnesium is 12.7% (11.6 At.%) at 710 K and likewise it decreases at higher and lower temperatures, being only about 1.5% (1.3 At.%) at 373 K. Thus the region of solid solution for this system is even more limited than that of the aluminum-copper alloy system.

There are 40 sets of experimental thermal conductivity data available for this system. Of the 22 data sets for Al + Mg alloys listed in Table 6 and shown in Figure 11, seven sets are merely single data points. Of the 18 data sets for Mg + Al alloys listed in Table 7 and shown in Figure 12, 10 sets are single data points.

For the Al + Mg alloys, measurements were limited to specimens containing no more than 15% Mg. The recommended curves are, therefore, given for 0.5 to 10% Mg alloys only. They follow the general trend of the data of Johnson [56] (Al + Mg curves 5 and 6) and Powell, et al. [57] (Al + Mg curves 18-22) at low temperatures and the data of Mikryukov and Karagezyan [58] (Al + Mg curves 8-11) at high temperatures. At 300 K the k_e values were calculated from eq. (12), and the k_g values at 300 K were derived as the differences between k and k_e values. These k_g values were extrapolated to higher temperatures up to the sodidus points according to the temperature dependence of eq. (35) and to lower temperatures according to the pattern of k_g curves derived from the available experimental k and the calculated k_e around the region of maximum k_g and according to T^2 dependence at lower temperatures assuming k_g to be negligible at 1 K. The total thermal conductivity values were then obtained by adding the extrapolated k_g and the calculated k_e. The resulting recommended values agree with the data of Powell et al. [57] (Al + Mg curves 18-20) at low temperatures to within 10% and with the data of Meyer-Rassler [122] (Al + Mg curve 7) and of Mikryukov and Karagezyan [58] (Al + Mg curves 8-11) at higher temperatures to within 8%. The k_g values are very uncertain and are merely to serve as correction terms for the derivation of the total thermal conductivities.

For the Mg + Al alloys, no measurements were made below 85 K and none for alloys containing more than 14% Al. The data of Smith [45] (Mg + Al curves 1 and 2) and Kikuchi [59] (Mg + Al curves 8-13) were favored in constructing the conductivity-composition curve for 300 K. The k_e values were calculated from eq. (12) and those at 300 K were plotted on the conductivity-composition graph. The k_g values at 300 K were taken as the differences between k and k_e values. These k_g values were similarly extrapolated to low and high temperatures according to the appropriate temperature dependences, which are very uncertain. The total thermal conductivity values were obtained by adding these k_g to the calculated k_e. Since

there is no information as to where the maxima of the k_g curves occur, no k_g values are given below 100 K and hence no total k values are reported at low temperatures for the dilute alloys, even though the k_e values are known. The k values of the 5 and 10% Al alloys are restricted to the range between 250 and 350 K, since electrical resistivity values are available only in this range. The recommended values are in agreement with the data of Kikuchi [59] (Mg + Al curves 8-13), Smith [45] (Mg + Al curves 1 and 2), and Giuliani [125] (Mg + Al curve 14) to within 6%.

The resulting recommended values for k, k_e, and k_g are tabulated in Table 5 for 10 alloy compositions. These values are for well-annealed alloys. The k values are also shown in Figures 9 and 10. The values of residual electrical resistivity for eight of the 10 alloys are also given in Table 5. The uncertainties of the k values are stated in a footnote to Table 5, while the uncertainties of the k_e and k_g values are indicated by their being designated as recommended, provisional, or typical values. The ranges of uncertainties of recommended, provisional, and typical values are less than ±15%, between ±15 and ±30%, and greater than ±30%, respectively.

TABLE 5. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-MAGNESIUM ALLOY SYSTEM†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Al: 99.50% (99.45 At.%) Mg: 0.50% (0.55 At.%)				Al: 99.00% (98.89 At.%) Mg: 1.00% (1.11 At.%)				Al: 97.00% (96.68 At.%) Mg: 3.00% (3.32 At.%)				Al: 95.00% (94.48 At.%) Mg: 5.00% (5.52 At.%)			
ρ_0 = 0.210 $\mu\Omega$ cm				ρ_0 = 0.420 $\mu\Omega$ cm				ρ_0 = 1.260 $\mu\Omega$ cm				ρ_0 = 2.10 $\mu\Omega$ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.476			4	0.240			4	0.0809			4	0.0486		
6	0.720			6	0.365			6	0.124			6	0.0738		
8	0.968			8	0.494			8	0.168			8	0.0988		
10	1.23			10	0.625			10	0.213			10	0.125		
15	1.81			15	0.942			15	0.328			15	0.191		
20	2.34			20	1.25			20	0.343			20	0.257		
25	2.76			25	1.52			25	0.552			25	0.322		
30	3.10			30	1.75			30	0.659			30	0.386		
40	3.50			40	2.09			40	0.835			40	0.504		
50	3.56			50	2.23			50	0.964			50	0.600		
60	3.31			60	2.21			60	1.05			60	0.675		
70	2.95			70	2.10			70	1.10			70	0.728		
80	2.64			80	1.98			80	1.12			80	0.768		
90	2.38			90	1.89			90	1.13			90	0.800		
100	2.23	2.09	0.141‡	100	1.85	1.74	0.113‡	100	1.15	1.07	0.0849‡	100	0.832	0.761	0.0710‡
150	2.08*	1.96	0.117‡	150	1.84*	1.74	0.0974‡	150	1.28*	1.21	0.0731‡	150	0.978	0.916	0.0615‡
200	2.08*	1.98	0.0978‡	200	1.89*	1.81	0.0832‡	200	1.40*	1.34	0.0631‡	200	1.10	1.05	0.0535‡
250	2.11*	2.03	0.0841‡	250	1.96*	1.89	0.0723‡	250	1.50*	1.44	0.0555‡	250	1.21	1.16	0.0474‡
273	2.14*	2.06	0.0791‡	273	2.00*	1.93	0.0684‡	273	1.54*	1.49	0.0528‡	273	1.25	1.21	0.0449‡
300	2.17	2.10	0.0739‡	300	2.03	1.97	0.0640‡	300	1.57	1.52	0.0498‡	300	1.29	1.25	0.0425‡
350	2.22	2.16	0.0658‡	350	2.10	2.04	0.0574‡	350	1.63	1.59	0.0451‡	350	1.36	1.32	0.0387‡
400	2.24	2.18	0.0590‡	400	2.13	2.08	0.0520‡	400	1.68	1.64	0.0413‡	400	1.41	1.38	0.0356‡
500	2.24	2.19	0.0491‡	500	2.14	2.10	0.0438‡	500	1.73	1.69	0.0356‡	500	1.47	1.44	0.0308‡
600	2.21	2.17	0.0419‡	600	2.13	2.10	0.0379‡	600	1.75	1.72	0.0315‡	600	1.50	1.48	0.0274‡
700	2.16	2.13	0.0366‡	700	2.09	2.06	0.0334‡	700	1.76	1.74	0.0283‡	700	1.53	1.51	0.0247‡
800	2.10*	2.07	0.0325‡	800	2.04*	2.02	0.0298‡	800	1.76*	1.74	0.0257‡	800	1.55*	1.54	0.0225‡
900	2.03*	2.00	0.0291‡	900	1.99*	1.97	0.0270‡	881	1.76*	1.74	0.0240‡	849	1.55*	1.53	0.0216‡
922	2.02*	1.99	0.0286‡	913	1.98*	1.96	0.0267‡								

† Uncertainties of the total thermal conductivity, k, are as follows:
- 99.50 Al - 0.50 Mg: ±10% below 200 K and ±6% above 200 K
- 99.00 Al - 1.00 Mg: ±10% below 200 K and ±6% above 200 K.
- 97.00 Al - 3.00 Mg: ±12% below 100 K, ±7% between 100 and 500 K, and ±8% above 500 K.
- 95.00 Al - 5.00 Mg: ±12% below 100 K, ±7% between 100 and 500 K, and ±8% above 500 K.

‡ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 5. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-MAGNESIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Al: 90.00% (89.02 At.%) Mg: 10.00% (10.98 At.%)				Al: 10.00% (9.10 At.%) Mg: 90.00% (90.90 At.%)				Al: 5.00% (4.53 At.%) Mg: 95.00% (95.47 At.%)				Al: 3.00% (2.71 At.%) Mg: 97.00% (97.29 At.%)			
ρ_0 = 4.078 μΩ cm												ρ_0 = 4.78 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0240			4				4				4		0.0204	
6	0.0370			6				6				6		0.0307	
8	0.0505			8				8				8		0.0409	
10	0.0647			10				10				10		0.0508	
15	0.0967			15				15				15		0.0752	
20	0.126			20				20				20		0.0998	
25	0.160			25				25				25		0.124	
30	0.204			30				30				30		0.148	
40	0.266			40				40				40		0.192	
50	0.321			50				50				50		0.232	
60	0.370			60				60				60		0.266	
70	0.412			70				70				70		0.295	
80	0.449			80				80				80		0.318	
90	0.485			90				90				90		0.339	
100	0.519	0.462	0.0572§	100			0.0564§	100			0.0723§	100	0.453*	0.362	0.0911§
150	0.653	0.603	0.0498§	150			0.0477§	150			0.0613§	150	0.553*	0.476	0.0771§
200	0.763	0.719	0.0437§	200			0.0409§	200			0.0527§	200	0.634*	0.568	0.0659§
250	0.852	0.813	0.0386§	250	0.444‡	0.408	0.0358§	250	0.576	0.530	0.0460§	250	0.699*	0.642	0.0572§
273	0.888	0.851	0.0370§	273	0.461‡	0.427	0.0338§	273	0.598	0.554	0.0435§	273	0.728*	0.674	0.0540§
300	0.926	0.891	0.0350§	300	0.477‡	0.445	0.0317§	300	0.619	0.578	0.0407§	300	0.756	0.705	0.0505§
350	0.990	0.957	0.0320§	350	0.504‡	0.475	0.0285§	350	0.653	0.616	0.0367§	350	0.799*	0.754	0.0452§
400	1.04	1.01	0.0296§	400			0.0259§	400			0.0334§	400	0.835*	0.794	0.0408§
500	1.12	1.10	0.0257§	500			0.0220§	500			0.0283§	500	0.888*	0.854	0.0343§
600	1.17	1.15	0.0230§	600			0.0191§	600			0.0247§	600	0.924*	0.894	0.0295§
700	1.20	1.18	0.0208§	700			0.0170§	700			0.0218§	700	0.946*	0.920	0.0260§
788	1.22	1.21	0.0193§	756			0.0159§	800			0.0196§	800	0.964*	0.941	0.0232§
								839			0.0189§	872	0.975*	0.953	0.0216§

† Uncertainties of the total thermal conductivity, k, are as follows:
90.00 Al - 10.00 Mg: ±12% below 100 K, ±7% between 100 and 500 K, and ±8% above 500 K.
10.00 Al - 90.00 Mg: ±15% between 250 and 350 K.
5.00 Al - 95.00 Mg: ±12% between 250 and 350 K.
3.00 Al - 97.00 Mg: ±10% below 200 K, ±6% between 200 and 500 K, and ±8% above 500 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 5. RECOMMENDED THERMAL CONDUCTIVITY OF ALUMINUM-MAGNESIUM ALLOY SYSTEM (continued) †

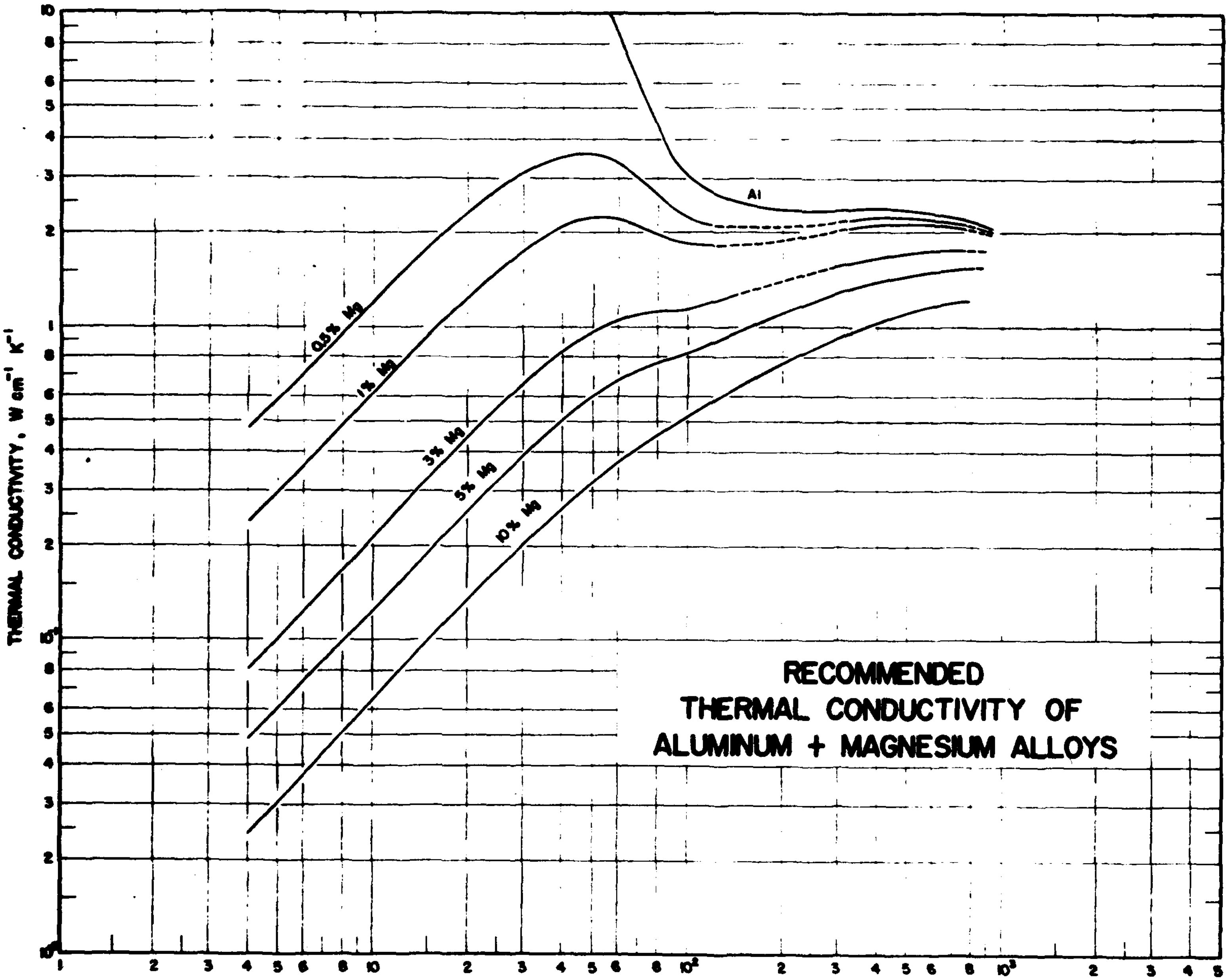
[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Al: 1.00% (0.90 At.%) Mg: 99.00% (99.10 At.%)				Al: 0.50% (0.45 At.%) Mg: 99.50% (99.55 At.%)			
ρ_0 = 1.980 μΩ cm				ρ_0 = 0.980 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g
4		0.0500		4		0.0996	
6		0.0750		6		0.150	
8		0.100		8		0.200	
10		0.125		10		0.249	
15		0.186		15		0.369	
20		0.245		20		0.481	
25		0.301		25		0.586	
30		0.355		30		0.683	
40		0.451		40		0.838	
50		0.525		50		0.920	
60		0.573		60		0.950	
70		0.602		70		0.962	
80		0.619		80		0.971	
90		0.634		90		0.978	
100	0.793	0.660	0.133‡	100	1.07*	0.982	0.152‡
150	0.904	0.792	0.112‡	150	1.18*	1.05	0.127‡
200	0.989	0.896	0.0932‡	200	1.23*	1.13	0.104‡
250	1.05	0.972	0.0797‡	250	1.27*	1.18	0.0874‡
273	1.08	1.01	0.0746‡	273	1.29*	1.21	0.0816‡
300	1.10	1.03	0.0692‡	300	1.30*	1.23	0.0756‡
350	1.14	1.08	0.0613‡	350	1.32*	1.25	0.0661‡
400	1.17	1.12	0.0546‡	400	1.33	1.27	0.0589‡
500	1.19	1.15	0.0449‡	500	1.34	1.29	0.0481‡
600	1.21	1.17	0.0382‡	600	1.34	1.30	0.0406‡
700	1.22	1.19	0.0331‡	700	1.33	1.30	0.0350‡
800	1.22	1.19	0.0292‡	800	1.33*	1.30	0.0308‡
900	1.22	1.19	0.0262‡	900	1.32*	1.30	0.0274‡
906	1.22	1.19	0.0260‡	914	1.32*	1.30	0.0270‡

† Uncertainties of the total thermal conductivity, k, are as follows:
1.00 Al - 99.00 Mg: ±12% below 200 K, ±6% between 200 and 500 K, and ±8% above 500 K.
0.50 Al - 99.50 Mg: ±12% below 200 K, ±6% between 200 and 500 K, and ±8% above 500 K.

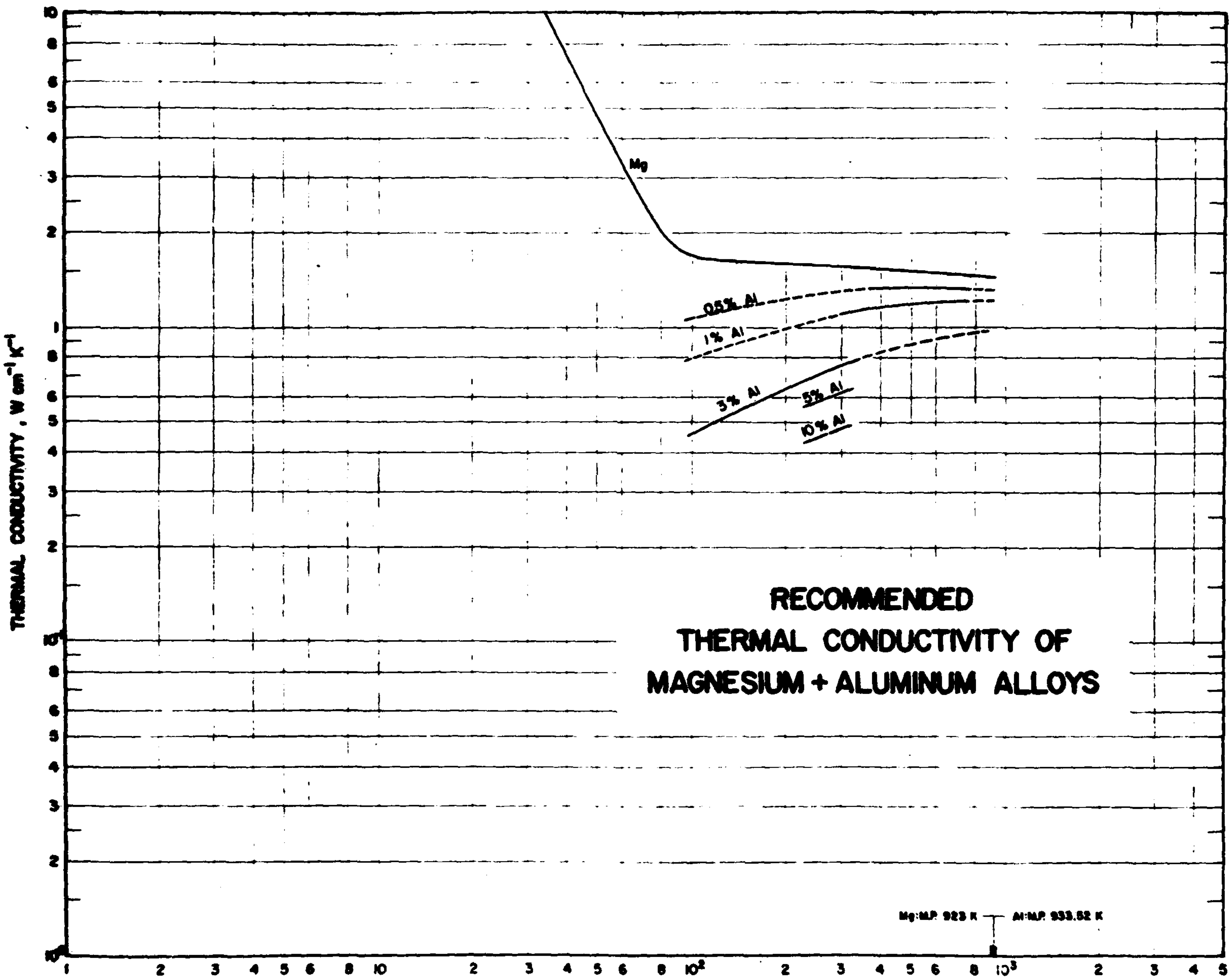
‡ Typical value.

* In temperature range where no experimental thermal conductivity data are available.



. TPRC

FIGURE 9



TPRC

FIGURE 10

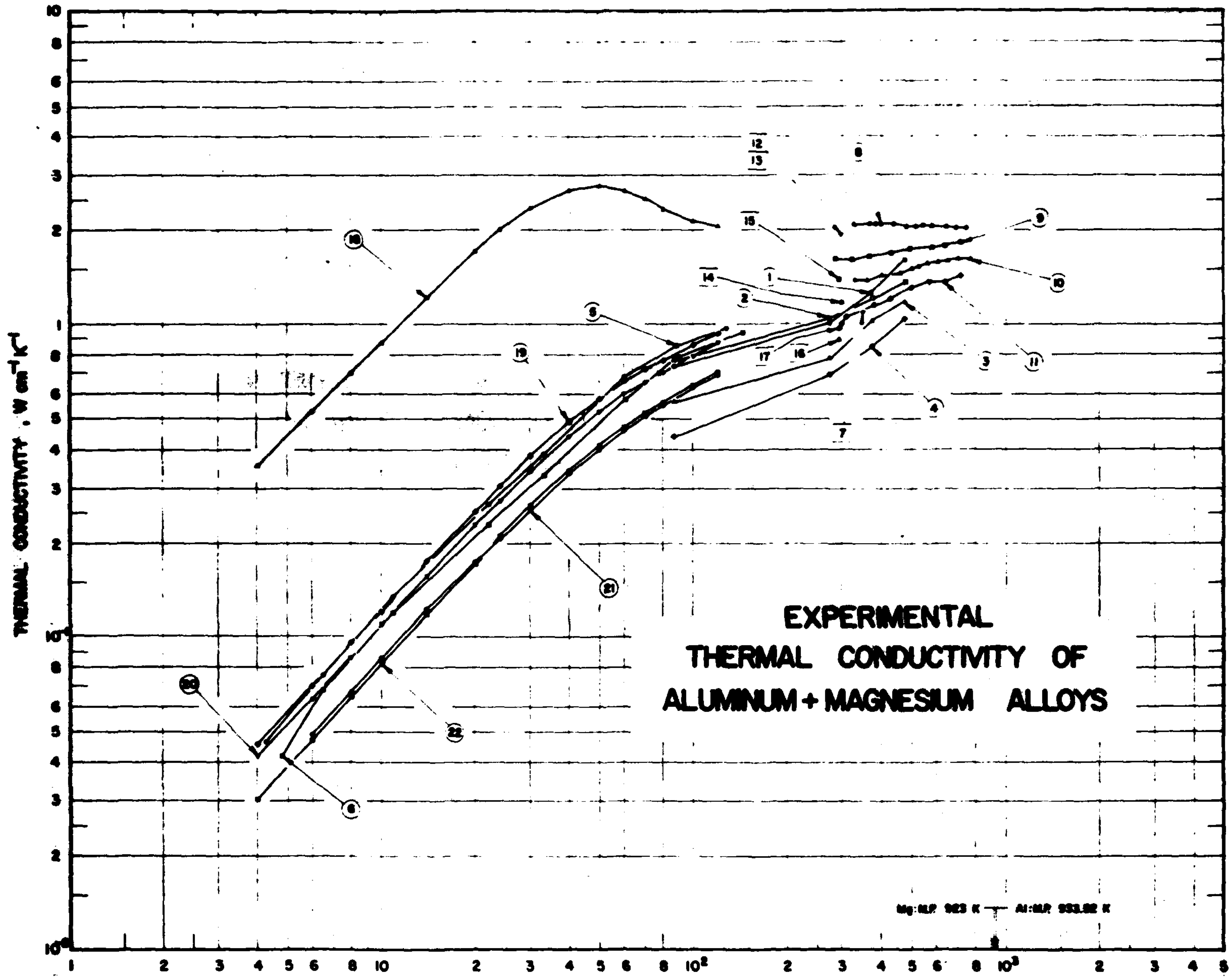
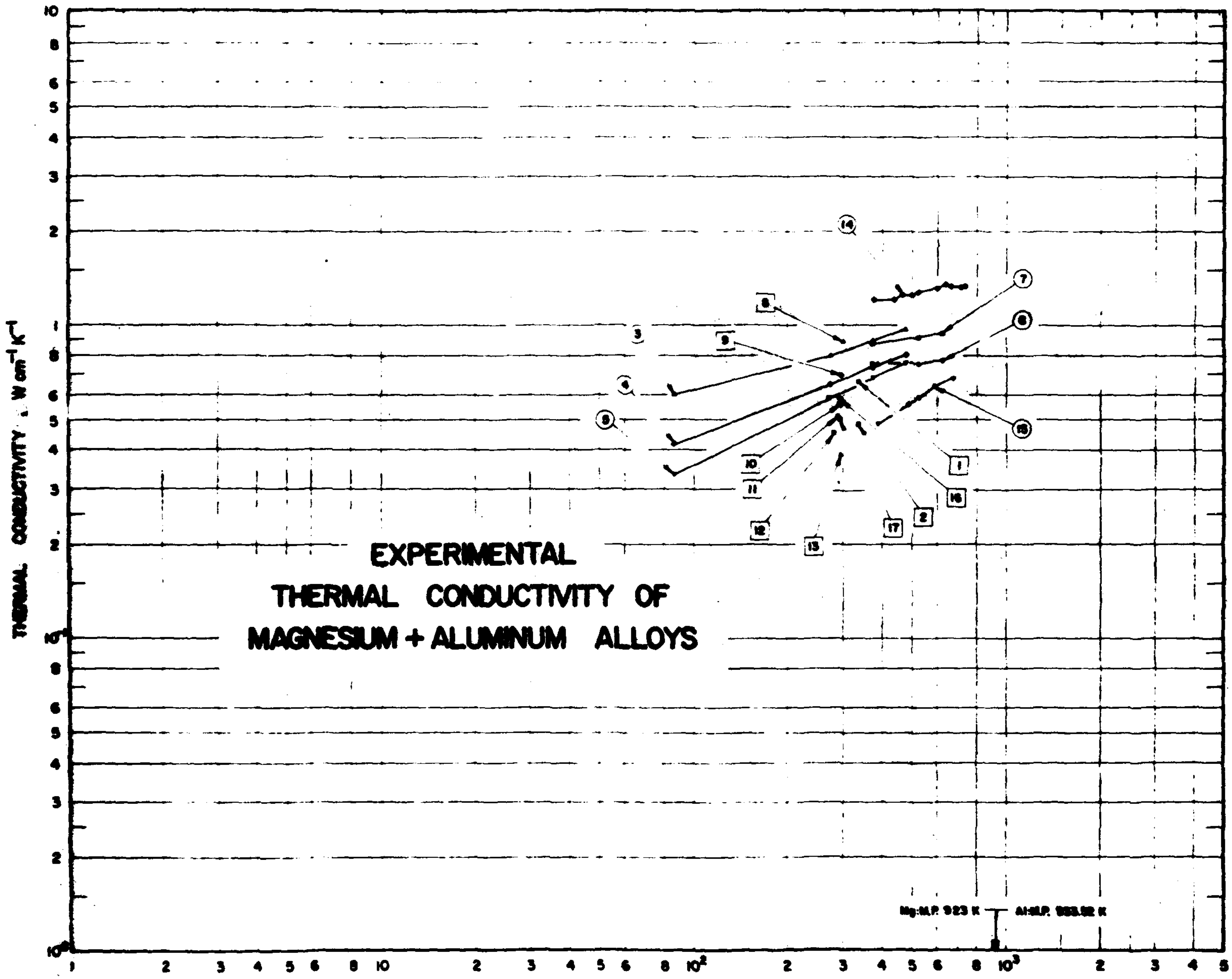

EXPERIMENTAL
THERMAL CONDUCTIVITY OF
ALUMINUM + MAGNESIUM ALLOYS
THERMAL CONDUCTIVITY, W cm⁻¹ K⁻¹
TEMPERATURE , K
Mg: M.P. 923 K
Al: M.P. 933.52 K
TPRC

FIGURE 11



TPRC

FIGURE 12

TABLE 6. THERMAL CONDUCTIVITY OF ALUMINUM - MAGNESIUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Mg	Composition (continued), Specifications, and Remarks
1	41	Mannchen, W.	1931	L	87-476		92.0	8.0	Cast; electrical conductivity reported as 20.02, 13.21, 10.5, and 5.5 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 87, 273, 373, and 476 K, respectively.
2	41	Mannchen, W.	1931	L	87-476		92.0	8.0	Annealed; electrical conductivity reported as 24.5, 15.05, 12.25, and 10.25 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 87, 273, 373, and 476 K, respectively.
3	41	Mannchen, W.	1931	L	87-476		88.0	12.0	Cast; electrical conductivity reported as 19.6, 11.95, 9.4, and 7.55 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 87, 273, 373, and 476 K, respectively.
4	41	Mannchen, W.	1931	L	87-476		86.0	14.0	Annealed; electrical conductivity reported as 12.7, 8.96, 8.05, and 7.6 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 87, 273, 373, and 476 K, respectively.
5	56	Johnson, E.W.	1960		4.3-128	5052	97.7-97.1	2.2-2.8	0.10 Mn; annealed.
6	56	Johnson, E.W.	1960		4.8-144	5154	96.8-96.0	3.1-3.9	0.10 Mn; annealed.
7	122	Meyer-Rassler, E.	1940		348.2	Magnalium	93.0	7.0	15 mm in diameter and 72 mm long; density 2.63 g cm^{-3}.
8	58	Mikryukov, V.E. and Karagezyan, A.G.	1961	E	327-746		99.3	0.7	3 mm diameter and 300 mm long; prepared from 99.9 pure Al.
9	58	Mikryukov, V.E. and Karagezyan, A.G.	1961	E	285-716		97.0	3.0	Similar to the above specimen.
10	58	Mikryukov, V.E. and Karagezyan, A.G.	1961	E	330-766		95.0	5.0	Similar to the above specimen.
11	58	Mikryukov, V.E. and Karagezyan, A.G.	1961	E	289-717		92.0	8.0	Similar to the above specimen.
12	123	Materials in Design Engineering	1959		298.2	5005	Bal.	0.8	Nominal composition; annealed at 617 K; density 2.68 g cm^{-3}; electrical resistivity 3.4 $\mu\Omega$ cm at 20 C.
13	123	Materials in Design Engineering	1959		298.2	5050	Bal.	1.0~1.8	Nominal composition; annealed at 617 K; density 2.68 g cm^{-3}.
14	123	Materials in Design Engineering	1959		298.2	5056	Bal.	4.7~5.6	0.05~0.20 Cr and 0.05~0.20 Mn (nominal composition); annealed at 617 K; density 2.63 g cm^{-3}; electrical resistivity 5.94 $\mu\Omega$ cm at 20 C.
15	123	Materials in Design Engineering	1959		293.2	G4A	96.0	4.0	Nominal composition; as cast; density 2.63 g cm^{-3}.
16	123	Materials in Design Engineering	1959		293.2	G10A	96.0	4.0	Nominal composition; as cast; density 2.57 g cm^{-3}.
17	123	Materials in Design Engineering	1959		293.2	G8A	92.0	8.0	Nominal composition; as cast; density 2.57 g cm^{-3}.
18	97	Powell, R. L., Hall, W.J. and Roder, H.M.	1960	L	4-120	6063-T5	Bal.	0.65	0.38 Si, 0.1 each Fe, Ga, Mn, 0.01 each Cr, Cu, Ti, V, Zn, 0.001 Ca, and 0.001 Pb; 3.66 mm diameter rod specimen; grain size 0.062 mm x 0.048 mm (longitudinal) and 0.062 mm (transverse); precipitation heat-treated; electrical resistivity 0.28, 0.28, 0.33, 0.43, 0.8, 2.3, and 3.5 $\mu\Omega$ cm at 4, 10, 40, 60, 100, 200, and 300 K, respectively; smoothed values reported.

TABLE 6. THERMAL CONDUCTIVITY OF ALUMINUM + MAGNESIUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Mg	Composition (continued), Specifications, and Remarks
19	57	Powell, R. L., Hall, W.J. and Roder, H.M.	1960	L	4-120	5052-O	Bal.	2.46	0.22 Cr, 0.1 each Cu, Fe, Si, Ga, Mn, Zn, 0.01 Ti, 0.01 V, 0.001 Ca, and 0.001 Zr; grain size 0.056 mm x 0.032 mm (longitudinal) and 0.040 mm (transverse); annealed in vacuum for 1 hr at 350 C; electrical resistivity 2.0, 2.1, 2.2, 2.7, 4.4, and 5.0 μΩ cm at 4, 20, 60, 100, 200, and 300 K, respectively; smoothed values reported.
20	57	Powell, R. L., et al.	1960	L	4-120	5154-O	Bal.	3.32	0.21 Cr, 0.1 each Cu, Fe, Si, Mn, 0.01 each Ti, V, Zn, 0.001 Ca, and 0.001 Pb; grain size 0.036 mm x 0.028 mm (longitudinal) and 0.032 mm (transverse); annealed in vacuum for 1 hr at 350 C; electrical resistivity 2.2, 2.3, 2.4, and 2.5 μΩ cm at 4, 10, 30, and 60 K, respectively; smoothed values reported.
21	57	Powell, R. L., et al.	1960	L	6-120	5083-O	Bal.	4.44	0.7 Mn, 0.1 each Cr, Fe, Si, 0.04 Cu; supplied by R.D. Olleman, Kaiser Aluminum and Chemical Co.; average crystal grain size 0.74 mm x 0.21 mm (longitudinal) and 0.54 mm x 0.14 mm (transverse); annealed in vacuum for 1 hr at 350 C.
22	57	Powell, R. L., et al.	1960	L	4-120	5086-F	Bal.	4.10	0.51 Mn, 0.28 Fe, 0.1 each Cr, Si, Zn, 0.07 Cu, and 0.02 Ti; average crystal grain size 0.061 mm x 0.022 mm (longitudinal) and 0.086 mm x 0.020 mm (transverse); as fabricated; electrical resistivity 3.0, 3.0, 3.1, 3.6, 5.0, and 5.7 μΩ cm at 4, 40, 60, 100, 200, and 300 K, respectively; smoothed values reported.

TABLE 7. THERMAL CONDUCTIVITY OF MAGNESIUM - ALUMINUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Mg	Al	Composition (continued), Specifications, and Remarks
1	45	Smith, A.W.	1925	L	336.2		95.82	4.12	0.028 Fe and 0.019 Si; ~5 cm long and 0.3 cm^2 in cross-section; supplied by Aluminum Co. of America; electrical conductivity 9.06 x 10^4 Ω^{-1} cm^{-1} at 63 C.
2	45	Smith, A.W.	1925	L	336.2		89.82	10.12	0.023 Si and 0.028 Fe; similar to the above specimen except electrical conductivity 6.00 x 10^4 Ω^{-1} cm^{-1} at 63 C.
3	124, 41	Staebler, J.; Mannchen, W.	1929 1931	L	87-476		94.0	6.0	1.23 cm^2 in cross-section and 3 cm long; cast; electrical conductivity 14.7, 8.04, 6.47, and 5.99 x 10^4 Ω^{-1} cm^{-1} at 87, 273, 373, and 476 K, respectively.
4	124, 41	Staebler, J.; Mannchen, W.	1929 1931	L	87-476		92.0	8.0	1.23 cm^2 in cross-section and 3 cm long; electrical conductivity 13.32, 7.31, 5.95, and 5.55 x 10^4 Ω^{-1} cm^{-1} at 87, 273, 373, and 476 K, respectively.
5	124, 41	Staebler, J.; Mannchen, W.	1929 1931	L	87-476		88	12	1.23 cm^2 in cross-section and 3 cm long; electrical conductivity 9.65, 5.99, 5.27, and 4.90 x 10^4 Ω^{-1} cm^{-1} at 87, 273, 373, and 476 K, respectively.
6	60	Maybrey, H.J.	1928	L	373-623		94	6	12 in. long and 1 in. in diameter; annealed at 300 C for 3 hr.
7	60	Maybrey, H.J.	1928	L	373-623		89	11	Similar to the above specimen.
8	50	Kikuchi, R.	1932	E	300.2		97.9	2.1	3 mm diameter and 200 mm long; electrical conductivity 11.9 x 10^4 Ω^{-1} cm^{-1} at 27 C.
9	50	Kikuchi, R.	1932	E	295.5		95.8	4.2	3 mm diameter and 200 mm long; electrical conductivity 8.9 x 10^4 Ω^{-1} cm^{-1} at 22.3 C.
10	50	Kikuchi, R.	1932	E	295.1		93.8	6.2	3 mm diameter and 200 mm long; electrical conductivity 6.9 x 10^4 Ω^{-1} cm^{-1} at 21.9 C.
11	50	Kikuchi, R.	1932	E	291.5		91.8	8.2	3 mm diameter and 200 mm long; electrical conductivity 5.9 x 10^4 Ω^{-1} cm^{-1} at 18.3 C.
12	50	Kikuchi, R.	1932	E	281.5		89.7	10.3	3 mm diameter and 200 mm long; electrical conductivity 5.5 x 10^4 Ω^{-1} cm^{-1} at 19.3 C.
13	50	Kikuchi, R.	1932	E	296.5		87.8	12.2	3 mm diameter and 200 mm long; electrical conductivity 5.1 x 10^4 Ω^{-1} cm^{-1} at 23.1 C.
14	125	Giuliani, S.	1967	C	375-736	Magnox; Al 80		0.80	0.0050 Be, 0.0020 Mn, and 0.0004 Cu; 1.2 to 1.3 cm in diameter and 1.8 to 2.5 cm long; Armco iron used as comparative material.
15	125	Giuliani, S.	1967	C	387-674	Magnox; Atesia T		8-9	0.5-1 Zn and 0.2 Mn; 1.2 to 1.3 cm in diameter and 1.8 to 2.5 cm long; Armco iron used as comparative material.
16	123	Materials in Design Engineering	1959		293.2	AZ6aA-F		5.8-7.2	0.4-1.5 Zn and >0.15 Mn (nominal composition); density 1.80 g cm^{-3}; electrical resistivity 12.5 $\mu\Omega$ cm at 20 C.
17	123	Materials in Design Engineering	1960		293.2	AZ80A-T		7.8-9.2	0.2-0.8 Zn and >0.12 Mn (nominal composition); density 1.83 g cm^{-3}; electrical resistivity 14.5 $\mu\Omega$ cm at 20 C.
18*	173	Powell, R.W., Hickman, M.J., and Tye, R.P.	1964	C	323-773	Magnox B		1.0	0.002-0.003 Be; 2.5 cm diameter x 20* cm long; electrical resistivity 6.05, 6.5, 7.3, 8.9, 10.6, 12.3, and 14.15 $\mu\Omega$ cm at 20, 50, 100, 200, 300, 400, and 500 C, respectively.

* Not shown in figure.

4.3. Copper-Gold Alloy System

The copper-gold alloy system forms a continuous series of solid solutions over the entire range of compositions. Ordered structures are formed at temperatures below about 663 K for compositions ranging from about 40 to 63% Au (17.7 to 35.5 At.% Au) and at temperatures below about 683 K for compositions ranging from about 63 to 94% Au (35.5 to 83.5 At.% Au). These ordered structures are due to the formation of the intermetallic compounds Cu_3Au (50.85% Au), CuAu (75.63% Au), and $CuAu_3$ (90.30% Au). In this work only the thermal conductivity data of disordered alloys are treated.

There are 75 sets of experimental data available for the thermal conductivity of this alloy system. Of the 17 data sets for Cu + Au alloys listed in Table 9 and shown in Figure 15, nine sets are merely single data points around room temperature. Of the 58 data sets for Au + Cu alloys listed in Table 10 and shown in Figure 16, 35 sets are single data points.

For the Cu + Au alloys, the data can be separated into three groups: the low temperature data of Grüneisen and Reddemann [61] (Cu + Au curves 1 and 2) and Kemp, et al. [62] (Cu + Au curves 8 and 9), the data of Sedström [63,64] (Cu + Au curves 10-15) at the ice point, and the five points around 440 K measured by Zolotukhin [65] (Cu + Au curves 3-7) for a partially ordered 5% Au. No data are available above 470 K. Hence, the experimental data are very limited. To derive recommended values, the electronic component k_e was calculated from eq. (12) and the lattice component k_g was calculated from eq. (35). The total k was obtained by adding k_g to k_e. The results agree with the data of Sedström [63] (Cu + Au curves 10, 12, 13, and 15) at the ice point and with the data of Kemp, et al. [62] (Cu + Cu curves 8 and 9) and of Leaver and Charsley [120] (Cu + Cu curve 16) at lower temperatures to within 8%. The recommended values are for disordered alloys only; hence Zolotukhin's data (Cu + Au curves 3-7) were not used for comparison. The recommended curves were extended to the solidus points at high temperatures. The curves for alloys containing 10% Au or less were not extended to temperatures below 40 K because of the large uncertainties of the calculated k_g values. For denser alloys, however, the curves were extended to 4 K using k_g values derived from the data of Kemp, et al. [62]. The k_g values for dilute alloys are extremely uncertain at low temperatures and are not reported below 60 K.

For the Au + Cu alloys, the experimental data were mostly obtained below the order-disorder transition temperature on specimens in the ordering range, except for two measurements made by Grüneisen and Reddemann [61] (Au + Cu curves 40 and 41) on specimens containing 1.57 and 3.10% Cu at low temperatures and one made by Goff, et al. [66] (Au + Cu curve 56) on a disordered Cu_3Au specimen. The recommended values for disordered alloys were derived from k_e calculated from eq. (12) and k_g calculated from eq. (35). Due to poor experimental data, detailed quantitative comparison of the calculated values

is not practical. However, the recommended values agree with the data of Grüneisen and Reddemann [61] (Au + Cu curves 38-41, 45, 46, and 48) at low temperatures and the data of Goff, et al. [66] (Au + Cu curves 56-58) from 60 to 300 K to within 10%. The recommended curves were extended to the solidus points at the high temperature end, but not below 40 K at the low temperature end owing to the large uncertainties of the calculated k_g values at very low temperatures, except for the curves for alloys with 45 and 50% Cu, which were extended to 4 K using the k_g values derived from the data of Kemp, et al. [62]. The k_g values for alloys containing 40% Cu or less are very uncertain at low temperatures and are not reported below 60 K.

The resulting recommended values for k, k_e, and k_g are tabulated in Table 8 for 25 alloy compositions. These values are for well-annealed disordered alloys. The values for k are also shown in Figures 13 and 14. The values of residual electrical resistivity for the alloys are also given in Table 8. The uncertainties of the k values are stated in a footnote to Table 8, while the uncertainties of the k_e and k_g values are indicated by their being designated as recommended, provisional, or typical values. The ranges of uncertainties of recommended, provisional, and typical values are less than ±15%, between ±15 and ±30%, and greater than ±30%, respectively.

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TABLE 8. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-GOLD ALLOY SYSTEM[*]

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 99.50% (99.84 At.%) Au: 0.50% (0.16 At.%)				Cu: 99.00% (99.68 At.%) Au: 1.00% (0.32 At.%)				Cu: 97.00% (99.01 At.%) Au: 3.00% (0.99 At.%)				Cu: 95.00% (98.33 At.%) Au: 5.00% (1.67 At.%)			
ρ_o = 0.10 $\mu\Omega$ cm				ρ_o = 0.20 $\mu\Omega$ cm				ρ_o = 0.530 $\mu\Omega$ cm				ρ_o = 0.870 $\mu\Omega$ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.977		4		0.489		4		0.164		4		0.112	
6		1.47		6		0.733		6		0.276		6		0.168	
8		1.95		8		0.977		8		0.369		8		0.225	
10		2.44		10		1.22		10		0.461		10		0.281	
15		3.66		15		1.83		15		0.691		15		0.421	
20		4.89		20		2.44		20		0.922		20		0.562	
25		5.76		25		2.96		25		1.14		25		0.697	
30		6.11		30		3.49		30		1.36		30		0.832	
40		6.76		40		4.17		40		1.73		40		1.08	
50		6.30		50		4.46		50		1.99		50		1.28	
60	5.57*	5.26	0.310‡	60	4.34*	4.09	0.250‡	60	2.29*	2.12	0.171‡	60	1.55*	1.41	0.136‡
70	4.80*	4.50	0.296‡	70	3.98*	3.74	0.238‡	70	2.34*	2.18	0.162‡	70	1.63*	1.50	0.128‡
80	4.37*	4.09	0.281‡	80	3.75*	3.52	0.226‡	80	2.36*	2.21	0.154‡	80	1.70*	1.58	0.121‡
90	4.12*	3.85	0.268‡	90	3.60*	3.38	0.215‡	90	2.39*	2.24	0.147‡	90	1.76*	1.64	0.115‡
100	4.01*	3.75	0.255‡	100	3.55*	3.34	0.205‡	100	2.44*	2.30	0.139‡	100	1.83*	1.72	0.110‡
150	3.92*	3.71	0.205‡	150	3.60*	3.44	0.165‡	150	2.74*	2.63	0.112‡	150	2.17*	2.08	0.0906‡
200	3.88*	3.71	0.170‡	200	3.65*	3.51	0.141‡	200	2.92*	2.82	0.0958‡	200	2.42*	2.34	0.0778‡
250	3.86*	3.71	0.147‡	250	3.68*	3.56	0.123‡	250	3.05*	2.97	0.0843‡	250	2.60*	2.53	0.0686‡
273	3.85*	3.71	0.138‡	273	3.70*	3.58	0.116‡	273	3.10*	3.02	0.0801‡	273	2.67	2.60	0.0652‡
300	3.85*	3.72	0.129‡	300	3.71*	3.60	0.109‡	300	3.15*	3.07	0.0757‡	300	2.74*	2.68	0.0618‡
350	3.86*	3.74	0.114‡	350	3.73*	3.63	0.0979‡	350	3.21*	3.14	0.0688‡	350	2.85*	2.79	0.0564‡
400	3.83*	3.73	0.103‡	400	3.72*	3.63	0.0890‡	400	3.26*	3.20	0.0633‡	400	2.92*	2.87	0.0520‡
500	3.77*	3.68	0.0861‡	500	3.69*	3.61	0.0755‡	500	3.32*	3.26	0.0548‡	500	3.03*	2.98	0.0453‡
600	3.71*	3.64	0.0738‡	600	3.65*	3.58	0.0656‡	600	3.34*	3.29	0.0486‡	600	3.08*	3.04	0.0403‡
700	3.65*	3.59	0.0647‡	700	3.60*	3.54	0.0581‡	700	3.35*	3.31	0.0437‡	700	3.12*	3.08	0.0365‡
800	3.60*	3.54	0.0575‡	800	3.55*	3.50	0.0521‡	800	3.34*	3.30	0.0398‡	800	3.14*	3.11	0.0335‡
900	3.55*	3.50	0.0518‡	900	3.50*	3.45	0.0473‡	900	3.31*	3.27	0.0366‡	900	3.14*	3.11	0.0309‡
1000	3.49*	3.44	0.0471‡	1000	3.45*	3.41	0.0433‡	1000	3.28*	3.25	0.0340‡	1000	3.13*	3.10	0.0288‡
1200	3.36*	3.32	0.0399‡	1200	3.33*	3.29	0.0370‡	1200	3.20*	3.17	0.0297‡	1200	3.09*	3.06	0.0254‡
1356	3.26*			1353	3.24*			1346	3.13*			1339	3.04*		

† Uncertainties of the total thermal conductivity, k, are as follows:
99.50 Cu - 0.50 Au: ± 15% below 100 K, ± 10% between 100 and 300 K, and ± 8% above 300 K.
99.00 Cu - 1.00 Au: ± 15% below 100 K, ± 10% between 100 and 300 K, and ± 8% above 300 K.
97.00 Cu - 3.00 Au: ± 15% below 200 K and ± 10% above 200 K.
95.00 Cu - 5.00 Au: ± 15% below 200 K and ± 10% above 200 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 8. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-GOLD ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 90.00% (96.54 At.%) Au: 10.00% (3.46 At.%)			
ρ_o = 1.72 μΩ cm			
T	k	k_e	k_g
4		0.0568	
6		0.0852	
8		0.117	
10		0.142	
15		0.213	
20		0.284	
25		0.353	
30		0.421	
40		0.553	
50		0.686	
60	0.856	0.756	0.100‡
70	0.932	0.838	0.0939‡
80	1.00	0.916	0.0886‡
90	1.07	0.982	0.0841‡
100	1.13*	1.05	0.0801‡
150	1.44*	1.37	0.0657‡
200	1.70*	1.64	0.0565‡
250	1.90*	1.85	0.0500‡
273	1.98	1.93	0.0476‡
300	2.08*	2.03	0.0452‡
350	2.22*	2.18	0.0414‡
400	2.33*	2.29	0.0383‡
500	2.50*	2.47	0.0335‡
600	2.61*	2.58	0.0300‡
700	2.70*	2.67	0.0274‡
800	2.76*	2.73	0.0252‡
900	2.80*	2.78	0.0234‡
1000	2.82*	2.80	0.0219‡
1200	2.84*	2.82	0.0195‡
1320	2.83*		

Cu: 85.00% (94.61 At.%) Au: 15.00% (5.39 At.%)			
ρ_o = 2.58 μΩ cm			
T	k	k_e	k_g
4	0.0462	0.0379	0.00829
6	0.746	0.0568	0.0178
8	0.104	0.0758	0.0287
10	0.134	0.0947	0.0397
15	0.205	0.142	0.0631
20	0.269	0.189	0.0799
25	0.324	0.234	0.0901
30	0.375	0.280	0.0950
40	0.462	0.368	0.0942
50	0.534	0.446	0.0879
60	0.600	0.518	0.0816‡
70	0.658	0.582	0.0763‡
80	0.714	0.642	0.0719‡
90	0.769	0.701	0.0682‡
100	0.824*	0.759	0.0649‡
150	1.08*	1.03	0.0532‡
200	1.31*	1.26	0.0437‡
250	1.50*	1.46	0.0406‡
273	1.58	1.54	0.0386‡
300	1.66*	1.62	0.0367‡
350	1.80*	1.77	0.0336‡
400	1.91*	1.88	0.0312‡
500	2.11*	2.08	0.0274‡
600	2.25*	2.23	0.0246‡
700	2.37*	2.35	0.0224‡
800	2.46*	2.44	0.0207‡
900	2.51*	2.49	0.0193‡
1000	2.56*	2.54	0.0181‡
1100	2.59*	2.57	0.0171‡
1303	2.63*		

Cu: 80.00% (92.54 At.%) Au: 20.00% (7.46 At.%)			
ρ_o = 3.52 μΩ cm			
T	k	k_e	k_g
4	0.0358	0.0278	0.00805
6	0.0580	0.0416	0.0164
8	0.0811	0.0555	0.0256
10	0.104	0.0694	0.0350
15	0.158	0.104	0.0542
20	0.206	0.139	0.0674
25	0.248	0.173	0.0755
30	0.286	0.206	0.0795
40	0.351	0.272	0.0789
50	0.407	0.333	0.0743
60	0.458	0.389	0.0694‡
70	0.506	0.441	0.0649‡
80	0.552	0.491	0.0610‡
90	0.597	0.539	0.0578‡
100	0.643	0.588	0.0550‡
150	0.861*	0.816	0.0450‡
200	1.06*	1.02	0.0388‡
250	1.22*	1.18	0.0344‡
273	1.29*	1.26	0.0328‡
300	1.37*	1.34	0.0311‡
350	1.50*	1.47	0.0286‡
400	1.62*	1.59	0.0265‡
500	1.81*	1.79	0.0234‡
600	1.97*	1.95	0.0210‡
700	2.09*	2.07	0.0192‡
800	2.19*	2.17	0.0178‡
900	2.26*	2.24	0.0166‡
1000	2.33*	2.31	0.0155‡
1100	2.39*	2.37	0.0147‡
1289	2.47*		

Cu: 75.00% (90.29 At.%) Au: 25.00% (9.71 At.%)			
ρ_o = 4.45 μΩ cm			
T	k	k_e	k_g
4	0.0299	0.0220	0.00788
6	0.0482	0.0329	0.0153
8	0.0675	0.0439	0.0236
10	0.0867	0.0549	0.0318
15	0.131	0.0823	0.0486
20	0.170	0.110	0.0598
25	0.204	0.137	0.0665
30	0.233	0.163	0.0697
40	0.284	0.216	0.0684
50	0.332	0.267	0.0647
60	0.373	0.312	0.0606‡
70	0.414	0.358	0.0565‡
80	0.453	0.400	0.0532‡
90	0.491	0.441	0.0503‡
100	0.530	0.482	0.0478‡
150	0.717*	0.678	0.0391‡
200	0.882*	0.848	0.0337‡
250	1.03*	1.00	0.0299‡
273	1.09	1.06	0.0285‡
300	1.17	1.14	0.0271‡
350	1.29	1.26	0.0249‡
400	1.40*	1.38	0.0231‡
500	1.59*	1.57	0.0204‡
600	1.74*	1.72	0.0184‡
700	1.87*	1.85	0.0168‡
800	1.97*	1.95	0.0156‡
900	2.05*	2.04	0.0145‡
1000	2.12*	2.11	0.0136‡
1100	2.18*	2.17	0.0129‡
1277	2.27*		

† Uncertainties of the total thermal conductivity, k, are as follows:
90.00 Cu - 10.00 Au: ±12% below 100 K, ± 8% between 100 and 400 K, and ± 10% above 400 K.
85.00 Cu - 15.00 Au: ±12% below 100 K, ± 8% between 100 and 400 K, and ± 10% above 400 K.
80.00 Cu - 20.00 Au: ± 10% below 200 K, ± 8% between 200 and 500 K, and ± 10% above 500 K.
75.00 Cu - 25.00 Au: ± 10% below 200 K, ± 8% between 200 and 500 K, and ± 10% above 500 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 8. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-GOLD ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 70.00% (87.85 At.%) Au: 30.00% (12.15 At.%)				Cu: 65.00% (85.20 At.%) Au: 35.00% (14.80 At.%)				Cu: 60.00% (82.30 At.%) Au: 40.00% (17.70 At.%)				Cu: 55.00% (79.12 At.%) Au: 45.00% (20.88 At.%)			
ρ_o = 5.47 μΩ cm				ρ_o = 6.52 μΩ cm				ρ_o = 7.52 μΩ cm				ρ_o = 8.48 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0256	0.0179	0.00772	4	0.0226	0.0150	0.00758	4	0.0205	0.0130	0.00746	4	0.0186	0.0115	0.00735
6	0.0413	0.0268	0.0145	6	0.0364	0.0225	0.0139	6	0.0327	0.0195	0.0132	6	0.0298	0.0173	0.0125
8	0.0575	0.0357	0.0218	8	0.0505	0.0300	0.0205	8	0.0452	0.0260	0.0192	8	0.0409	0.0230	0.0179
10	0.0739	0.0447	0.0292	10	0.0645	0.0375	0.0270	10	0.0575	0.0325	0.0250	10	0.0518	0.0288	0.0230
15	0.111	0.0670	0.0441	15	0.0962	0.0562	0.0400	15	0.0853	0.0487	0.0366	15	0.0765	0.0432	0.0333
20	0.143	0.0893	0.0539	20	0.124	0.0749	0.0488	20	0.109	0.0650	0.0444	20	0.0978	0.0576	0.0402
25	0.171	0.111	0.0596	25	0.147	0.0930	0.0540	25	0.130	0.0807	0.0491	25	0.116	0.0717	0.0445
30	0.195	0.133	0.0623	30	0.168	0.111	0.0566	30	0.148	0.0964	0.0515	30	0.132	0.0856	0.0468
40	0.236	0.175	0.0615	40	0.203	0.147	0.0559	40	0.178	0.127	0.0509	40	0.160	0.113	0.0467
50	0.275	0.217	0.0576	50	0.233	0.181	0.0522	50	0.204	0.157	0.0472	50	0.183	0.140	0.0430
60	0.309*	0.255	0.0537‡	60	0.262*	0.214	0.0482‡	60	0.230	0.186	0.0436‡	60	0.204*	0.164	0.0396‡
70	0.343*	0.293	0.0501‡	70	0.291*	0.246	0.0449‡	70	0.254	0.214	0.0405‡	70	0.228*	0.191	0.0369‡
80	0.376*	0.329	0.0470‡	80	0.319*	0.277	0.0421‡	80	0.279	0.241	0.0381‡	80	0.251*	0.216	0.0346‡
90	0.409*	0.364	0.0445‡	90	0.348*	0.308	0.0398‡	90	0.305	0.269	0.0360‡	90	0.274*	0.241	0.0327‡
100	0.442*	0.400	0.0423‡	100	0.377*	0.339	0.0379‡	100	0.331*	0.297	0.0342‡	100	0.296*	0.265	0.0311‡
150	0.603*	0.568	0.0346‡	150	0.518*	0.487	0.0309‡	150	0.456*	0.428	0.0279‡	150	0.410*	0.385	0.0254‡
200	0.750*	0.720	0.0298‡	200	0.651*	0.624	0.0267‡	200	0.576*	0.552	0.0241‡	200	0.520*	0.498	0.0219‡
250	0.886*	0.859	0.0265‡	250	0.773*	0.749	0.0237‡	250	0.687*	0.666	0.0214‡	250	0.622*	0.603	0.0194‡
273	0.942	0.917	0.0253‡	273	0.825*	0.802	0.0226‡	273	0.736	0.716	0.0204‡	273	0.666	0.647	0.0186‡
300	1.01	0.986	0.0240‡	300	0.886*	0.865	0.0215‡	300	0.791	0.772	0.0194‡	300	0.717	0.699	0.0176‡
350	1.12	1.10	0.0221‡	350	0.988*	0.968	0.0198‡	350	0.887	0.869	0.0179‡	350	0.807	0.791	0.0162‡
400	1.22*	1.20	0.0205‡	400	1.08*	1.06	0.0184‡	400	0.976	0.959	0.0166‡	400	0.890	0.875	0.0151‡
500	1.40*	1.38	0.0181‡	500	1.25*	1.23	0.0162‡	500	1.14*	1.13	0.0147‡	500	1.04*	1.03	0.0134‡
600	1.55*	1.53	0.0163‡	600	1.40*	1.39	0.0147‡	600	1.27*	1.26	0.0133‡	600	1.18*	1.17	0.0121‡
700	1.68*	1.67	0.0150‡	700	1.53*	1.52	0.0134‡	700	1.40*	1.39	0.0122‡	700	1.29*	1.28	0.0111‡
800	1.79*	1.78	0.0138‡	800	1.63*	1.62	0.0124‡	800	1.50*	1.49	0.0113‡	800	1.39*	1.38	0.0103‡
900	1.88*	1.87	0.0129‡	900	1.72*	1.71	0.0116‡	900	1.59*	1.58	0.0106‡	900	1.48*	1.47	0.00962‡
1000	1.96*	1.95	0.0122‡	1000	1.80*	1.79	0.0109‡	1000	1.67*	1.66	0.00993‡	1000	1.56*	1.55	0.00906‡
1100	2.03*	2.02	0.0115‡	1100	1.88*	1.87	0.0104‡	1100	1.74*	1.73	0.00939‡	1100	1.63*	1.62	0.00856‡
1265	2.12*			1255	1.97*			1245	1.82*			1236	1.71*		

† Uncertainties of the total thermal conductivity, k, are as follows:
70.00 Cu - 30.00 Au: ± 10% below 200 K, ± 8% between 200 and 500 K, and ± 10% above 500 K.
65.00 Cu - 35.00 Au: ± 10% below 200 K, ± 7% between 200 and 500 K, and ± 10% above 500 K.
60.00 Cu - 40.00 Au: ± 10% below 200 K, ± 7% between 200 and 500 K, and ± 10% above 500 K.
55.00 Cu - 45.00 Au: ± 10% below 200 K, ± 7% between 200 and 500 K, and ± 10% above 500 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 8. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-GOLD ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 50.00% (75.61 At.%) Au: 50.00% (24.39 At.%)				Cu: 45.00% (71.72 At.%) Au: 55.00% (28.28 At.%)				Cu: 40.00% (67.39 At.%) Au: 60.00% (32.61 At.%)				Cu: 35.00% (62.54 At.%) Au: 65.00% (37.46 At.%)			
ρ_o = 9.34 μΩ cm				ρ_o = 10.1 μΩ cm				ρ_o = 10.9 μΩ cm				ρ_o = 11.4 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0178	0.0105	0.00725	4	0.0168	0.00964	0.00717	4		0.00898		4		0.00855	
6	0.0277	0.0157	0.0120	6	0.0259	0.0144	0.0115	6		0.0135		6		0.0128	
8	0.0376	0.0209	0.0167	8	0.0350	0.0193	0.0157	8		0.0180		8		0.0171	
10	0.0474	0.0262	0.0212	10	0.0437	0.0241	0.0196	10		0.0224		10		0.0214	
15	0.0694	0.0392	0.0302	15	0.0636	0.0361	0.0275	15		0.0337		15		0.0321	
20	0.0887	0.0523	0.0364	20	0.0811	0.0482	0.0329	20		0.0449		20		0.0427	
25	0.105	0.0649	0.0402	25	0.0961	0.0599	0.0362	25		0.0557		25		0.0532	
30	0.120	0.0777	0.0422	30	0.110	0.0716	0.0379	30		0.0669		30		0.0636	
40	0.145	0.108	0.0421‡	40	0.133	0.0947	0.0380‡	40	0.126*	0.0885	0.0370‡	40	0.118*	0.0842	0.0342‡
50	0.166	0.127	0.0394‡	50	0.153	0.117	0.0360‡	50	0.143*	0.110	0.0334‡	50	0.135*	0.104	0.0309‡
60	0.187	0.151	0.0362‡	60	0.172	0.139	0.0333‡	60	0.161*	0.130	0.0307‡	60	0.152*	0.124	0.0283‡
70	0.207	0.173	0.0337‡	70	0.192	0.161	0.0309‡	70	0.179*	0.150	0.0285‡	70	0.169*	0.143	0.0263‡
80	0.228	0.196	0.0316‡	80	0.211	0.182	0.0290‡	80	0.197*	0.170	0.0267‡	80	0.187*	0.162	0.0247‡
90	0.250	0.220	0.0299‡	90	0.231	0.204	0.0274‡	90	0.216*	0.191	0.0252‡	90	0.204*	0.181	0.0233‡
100	0.271	0.243	0.0284‡	100	0.250	0.224	0.0260‡	100	0.234*	0.210	0.0240‡	100	0.222*	0.200	0.0221‡
150	0.376	0.353	0.0232‡	150	0.348	0.327	0.0212‡	150	0.326*	0.306	0.0196‡	150	0.310*	0.292	0.0180‡
200	0.476	0.456	0.0200‡	200	0.441	0.423	0.0183‡	200	0.413*	0.396	0.0168‡	200	0.394*	0.378	0.0156‡
250	0.570	0.552	0.0178‡	250	0.530	0.514	0.0163‡	250	0.496*	0.481	0.0150‡	250	0.473*	0.459	0.0138‡
273	0.612	0.595	0.0170‡	273	0.569	0.553	0.0156‡	273	0.534	0.520	0.0143‡	273	0.509	0.496	0.0132‡
300	0.660*	0.644	0.0161‡	300	0.614	0.599	0.0148‡	300	0.575	0.561	0.0136‡	300	0.549	0.536	0.0126‡
350	0.743*	0.728	0.0149‡	350	0.692	0.678	0.0136‡	350	0.651	0.638	0.0125‡	350	0.621	0.609	0.0116‡
400	0.823	0.809	0.0138‡	400	0.768	0.755	0.0127‡	400	0.721	0.709	0.0117‡	400	0.688	0.677	0.0108‡
500	0.967	0.955	0.0122‡	500	0.904	0.893	0.0112‡	500	0.850*	0.840	0.0103‡	500	0.812*	0.802	0.00954‡
600	1.09	1.08	0.0110‡	600	1.02	1.01	0.0102‡	600	0.966*	0.957	0.00935‡	600	0.922*	0.913	0.00864‡
700	1.20*	1.20	0.0101‡	700	1.13*	1.12	0.00932‡	700	1.07*	1.06	0.00859‡	700	1.02*	1.01	0.00793‡
800	1.30*	1.29	0.00942‡	800	1.22*	1.21	0.00865‡	800	1.16*	1.15	0.00797‡	800	1.11*	1.10	0.00736‡
900	1.39*	1.38	0.00881‡	900	1.30*	1.29	0.00810‡	900	1.23*	1.22	0.00746‡	900	1.18*	1.17	0.00689‡
1000	1.46*	1.45	0.00829‡	1000	1.38	1.37	0.00763‡	1000	1.30*	1.29	0.00703‡	1000	1.25*	1.24	0.00649‡
1100	1.53*	1.52	0.00786‡	1100	1.44*	1.43	0.00722‡	1100	1.37*	1.36	0.00666‡	1100	1.31*	1.30	0.00615‡
1226	1.62*			1216	1.51*			1206	1.43*	1.42	0.00632‡	1196	1.37*	1.36	0.00587‡

† Uncertainties of the total thermal conductivity, k, are as follows:
50.00 Cu - 50.00 Au: ±10% below 200 K, ±7% between 200 and 500 K, and ±10% above 500 K.
45.00 Cu - 55.00 Au: ±10% below 200 K, ±8% between 200 and 500 K, and ±10% above 500 K.
40.00 Cu - 60.00 Au: ±10% below 200 K, ±8% between 200 and 500 K, and ±10% above 500 K.
35.00 Cu - 65.00 Au: ±10% below 200 K, ±8% between 200 and 500 K, and ±10% above 500 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 8. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-GOLD ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 30.00% (57.05 At.%) Au: 70.00% (42.95 At.%)				Cu: 25.00% (50.82 At.%) Au: 75.00% (49.18 At.%)				Cu: 20.00% (43.66 At.%) Au: 80.00% (56.34 At.%)				Cu: 15.00% (35.36 At.%) Au: 85.00% (64.63 At.%)			
ρ_o = 11.8 μΩ cm				ρ_o = 12.0 μΩ cm				ρ_o = 11.7 μΩ cm				ρ_o = 10.8 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.00827		4		0.00818		4		0.00834		4		[illegible]	
6		0.0124		6		0.0123		6		0.0125		6		0.0136	
8		0.0165		8		0.0164		8		0.0167		8		0.0182	
10		0.0207		10		0.0204		10		0.0208		10		0.0227	
15		0.0310		15		0.0307		15		0.0313		15		0.0341	
20		0.0413		20		0.0409		20		0.0417		20		0.0454	
25		0.0514		25		0.0508		25		0.0518		25		0.0565	
30		0.0615		30		0.0607		30		0.0620		30		0.0675	
40	0.113*	0.0814	0.0318‡	40	0.110	0.0803	0.0296‡	40	0.110	0.0820	0.0277‡	40	0.115	0.0892	0.0262‡
50	0.129*	0.100	0.0286‡	50	0.127	0.0998	0.0267‡	50	0.127	0.102	0.0250‡	50	0.134	0.110	0.0236‡
60	0.146*	0.120	0.0263‡	60	0.143	0.118	0.0245‡	60	0.144	0.121	0.0229‡	60	0.153	0.131	0.0217‡
70	0.163*	0.139	0.0244‡	70	0.159	0.136	0.0227‡	70	0.161	0.140	0.0213‡	70	0.172	0.152	0.0201‡
80	0.180*	0.157	0.0229‡	80	0.176	0.155	0.0213‡	80	0.178	0.158	0.0199‡	80	0.191	0.172	0.0188‡
90	0.197*	0.175	0.0216‡	90	0.193*	0.173	0.0201‡	90	0.196*	0.177	0.0188‡	90	0.209	0.191	0.0178‡
100	0.214*	0.194	0.0205‡	100	0.209*	0.190	0.0191‡	100	0.213*	0.195	0.0178‡	100	0.228*	0.211	0.0169‡
150	0.299*	0.282	0.0167‡	150	0.294*	0.279	0.0155‡	150	0.299*	0.284	0.0145‡	150	0.321*	0.307	0.0137‡
200	0.381*	0.367	0.0144‡	200	0.375*	0.362	0.0134‡	200	0.381*	0.369	0.0125‡	200	0.409*	0.397	0.0118‡
250	0.458*	0.445	0.0128‡	250	0.452*	0.440	0.0119‡	250	0.459*	0.448	0.0111‡	250	0.492*	0.461	0.0105‡
273	0.492	0.480	0.0122‡	273	0.486	0.475	0.0114‡	273	0.493	0.482	0.0106‡	273	0.529	0.519	0.0100‡
300	0.531*	0.519	0.0116‡	300	0.525*	0.514	0.0108‡	300	0.532*	0.522	0.0101‡	300	0.570	0.560	0.00951‡
350	0.600*	0.589	0.0107‡	350	0.593*	0.583	0.00996‡	350	0.601*	0.592	0.00929‡	350	0.643	0.634	0.00875‡
400	0.666*	0.656	0.00997‡	400	0.658	0.649	0.00926‡	400	0.667	0.658	0.00864‡	400	0.712*	0.704	0.00814‡
500	0.786*	0.777	0.00884‡	500	0.775*	0.767	0.00820‡	500	0.785*	0.777	0.00765‡	500	0.836	0.829	0.00720‡
600	0.893*	0.885	0.00799‡	600	0.881*	0.874	0.00742‡	600	0.892*	0.885	0.00692‡	600	0.947*	0.940	0.00650‡
700	0.990*	0.983	0.00734‡	700	0.975*	0.968	0.00681‡	700	0.988*	0.982	0.00635‡	700	1.04*	1.03	0.00596‡
800	1.08*	1.07	0.00682‡	800	1.06*	1.05	0.00632‡	800	1.07*	1.06	0.00589‡	800	1.13*	1.12	0.00553‡
900	1.15*	1.14	0.00638‡	900	1.13*	1.12	0.00592‡	900	1.14*	1.13	0.00551‡	900	1.20*	1.20	0.00517‡
1000	1.21*	1.20	0.00601‡	1000	1.19*	1.18	0.00558‡	1000	1.21*	1.20	0.00520‡	1000	1.26*	1.26	0.00487‡
1100	1.27*	1.26	0.00570‡	1100	1.25*	1.24	0.00528‡	1100	1.26*	1.25	0.00492‡	1100	1.31*	1.31	0.00461‡
1188	1.32*	1.31	0.00547‡	1184	1.29*	1.28	0.00507‡	1182	1.30*	1.30	0.00473‡	1185	1.35*	1.35	0.00442‡

† Uncertainties of the total thermal conductivity, k, are as follows:
30.00 Cu - 70.00 Au: ±10% below 200 K, ±8% between 200 and 500 K, and ±10% above 500 K.
25.00 Cu - 75.00 Au: ±10% below 200 K, ±8% between 200 and 500 K, and ±10% above 500 K.
20.00 Cu - 80.00 Au: ±10% below 200 K, ±8% between 200 and 500 K, and ±10% above 500 K.
15.00 Cu - 85.00 Au: ±10% below 200 K, ±8% between 200 and 500 K, and ±10% above 500 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 8. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-GOLD ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 10.00% (25.62 At.%) Au: 90.00% (74.38 At.%)				Cu: 5.00% (14.03 At.%) Au: 95.00% (85.97 At.%)				Cu: 3.00% (8.75 At.%) Au: 97.00% (91.25 At.%)				Cu: 1.00% (3.04 At.%) Au: 99.00% (96.96 At.%)			
ρ_0 = 8.72 μΩ cm				ρ_0 = 5.27 μΩ cm				ρ_0 = 3.44 μΩ cm				ρ_0 = 1.40 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.0112		4		0.0185		4		0.0284		4		0.0698	
6		0.0168		6		0.0278		6		0.0426		6		0.105	
8		0.0224		8		0.0371		8		0.0568		8		0.140	
10		0.0280		10		0.0464		10		0.0701		10		0.174	
15		0.0420		15		0.0695		15		0.106		15		0.262	
20		0.0560		20		0.0927		20		0.142		20		0.349	
25		0.0696		25		0.114		25		0.174		25		0.420	
30		0.0832		30		0.136		30		0.206		30		0.492	
40	0.135	0.110	0.0254‡	40	0.204	0.178	0.0265‡	40	0.297	0.267	0.0300‡	40	0.663	0.622	0.0410‡
50	0.158	0.135	0.0229‡	50	0.242	0.218	0.0240‡	50	0.351	0.324	0.0271‡	50	0.758	0.721	0.0370‡
60	0.181	0.160	0.0210‡	60	0.278	0.256	0.0220‡	60	0.403	0.378	0.0248‡	60	0.848	0.814	0.0337‡
70	0.205	0.185	0.0195‡	70	0.314	0.294	0.0204‡	70	0.453	0.430	0.0229‡	70	0.932	0.901	0.0312‡
80	0.228	0.210	0.0183‡	80	0.350	0.331	0.0191‡	80	0.502	0.480	0.0215‡	80	1.01	0.981	0.0290‡
90	0.251	0.234	0.0172‡	90	0.385	0.367	0.0180‡	90	0.549	0.529	0.0201‡	90	1.09	1.06	0.0272‡
100	0.274*	0.258	0.0163‡	100	0.420*	0.403	0.0171‡	100	0.597*	0.578	0.0190‡	100	1.17*	1.14	0.0256‡
150	0.385*	0.372	0.0133‡	150	0.584*	0.570	0.0138‡	150	0.812*	0.797	0.0150‡	150	1.47*	1.45	0.0203‡
200	0.489*	0.478	0.0114‡	200	0.731*	0.719	0.0118‡	200	0.993*	0.980	0.0129‡	200	1.69*	1.68	0.0172‡
250	0.585*	0.575	0.0101‡	250	0.862*	0.852	0.0104‡	250	1.15*	1.14	0.0114‡	250	1.86*	1.84	0.0150‡
273	0.627	0.617	0.00964‡	273	0.918	0.908	0.00995‡	273	1.21	1.20	0.0108‡	273	1.92*	1.91	0.0142‡
300	0.675	0.666	0.00915‡	300	0.979	0.970	0.00943‡	300	1.28	1.27	0.0102‡	300	1.98*	1.97	0.0134‡
350	0.757	0.749	0.00841‡	350	1.08	1.07	0.00865‡	350	1.39	1.38	0.00935‡	350	2.08*	2.07	0.0122‡
400	0.834*	0.826	0.00781‡	400	1.17*	1.16	0.00801‡	400	1.49*	1.48	0.00865‡	400	2.16*	2.15	0.0112‡
500	0.967	0.960	0.00690‡	500	1.33*	1.32	0.00704‡	500	1.64*	1.63	0.00758‡	500	2.27*	2.26	0.00974‡
600	1.08*	1.07	0.00622‡	600	1.45*	1.44	0.00633‡	600	1.76*	1.75	0.00679‡	600	2.34*	2.33	0.00864‡
700	1.18*	1.17	0.00570‡	700	1.55*	1.54	0.00578‡	700	1.86*	1.85	0.00618‡	700	2.37*	2.36	0.00780‡
800	1.27*	1.26	0.00528‡	800	1.62*	1.61	0.00534‡	800	1.92*	1.91	0.00569‡	800	2.38*	2.37	0.00712‡
900	1.34*	1.34	0.00493‡	900	1.68*	1.68	0.00498‡	900	1.96*	1.95	0.00529‡	900	2.37*	2.36	0.00657‡
1000	1.39*	1.39	0.00464‡	1000	1.73*	1.73	0.00467‡	1000	1.98*	1.98	0.00495‡	1000	2.34*	2.33	0.00610‡
1100	1.44*	1.44	0.00439‡	1100	1.77*	1.77	0.00441‡	1100	1.99*	1.99	0.00466‡	1100	2.31*	2.30	0.00571‡
1190	1.48*	1.48	0.00417‡	1241	1.81*			1270	1.98*			1296	2.22*		

† Uncertainties of the total thermal conductivity, k, are as follows:
10.00 Cu - 90.00 Au: ± 10% below 200 K, ± 8% between 200 and 500 K, and ± 10% above 500 K.
5.00 Cu - 95.00 Au: ± 12% below 200 K, ± 8% between 200 and 500 K, and ± 10% above 500 K.
3.00 Cu - 97.00 Au: ± 12% below 200 K, ± 8% between 200 and 500 K, and ± 10% above 500 K.
1.00 Cu - 99.00 Au: ± 15% below 200 K and ± 10% above 200 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 8. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-GOLD ALLOY SYSTEM (continued)†

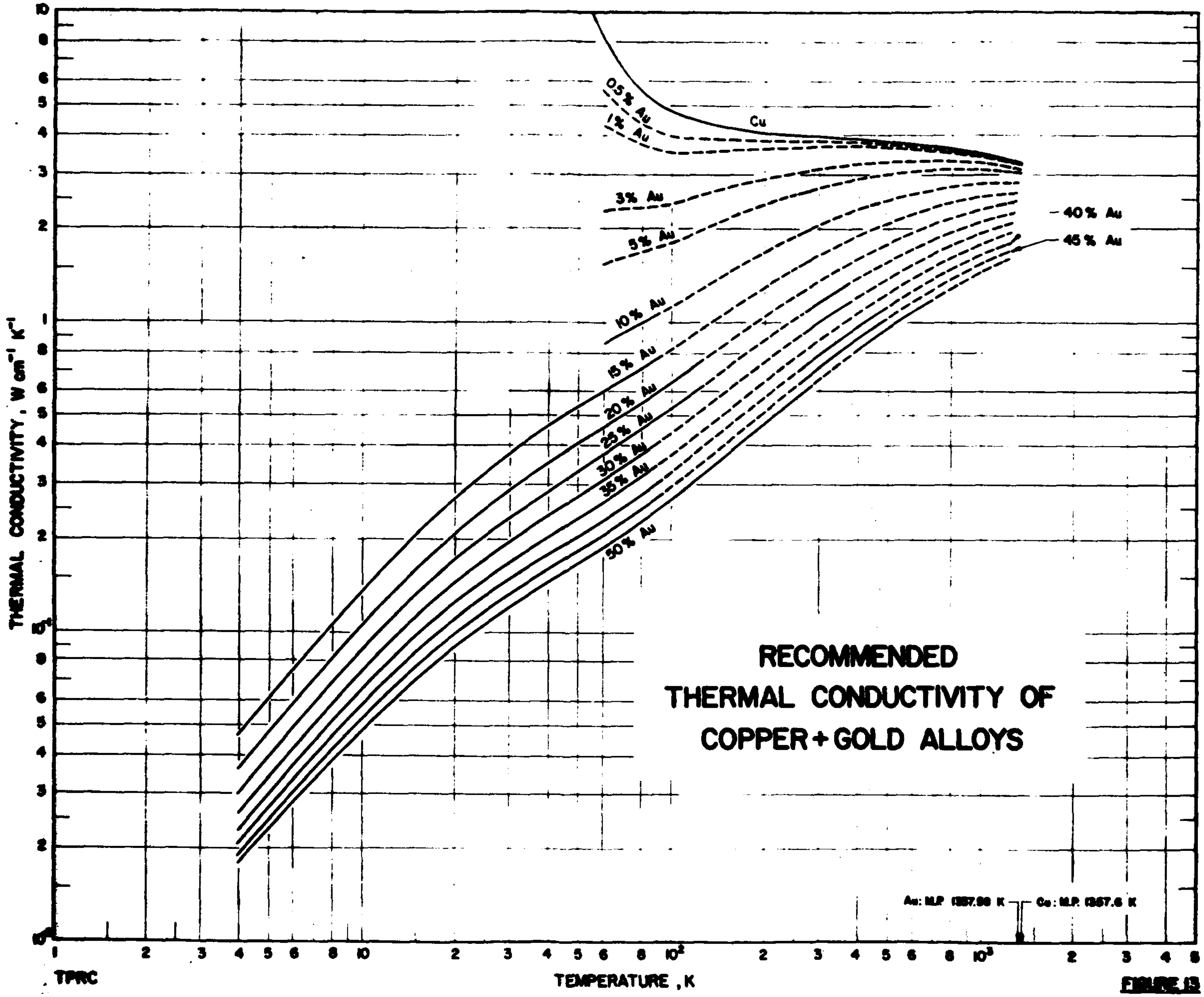
[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 0.50% (1.53 At.%) Au: 99.50% (98.47 At.%)						
ρ_0 = 0.770 μΩ cm						
T	k	k_e	k_g			
4		0.127				
6		0.190				
8		0.254				
10		0.317				
15		0.476				
20		0.634				
25		0.740				
30		0.843				
40	1.08*	1.03	0.0541‡			
50	1.20*	1.15	0.0480‡			
60	1.30*	1.26	0.0443‡			
70	1.39*	1.35	0.0409‡			
80	1.48*	1.44	0.0378‡			
90	1.56*	1.52	0.0351‡			
100	1.64*	1.61	0.0329‡			
150	1.96*	1.93	0.0257‡			
200	2.16*	2.14	0.0213‡			
250	2.30*	2.28	0.0185‡			
273	2.34*	2.32	0.0175‡			
300	2.39*	2.37	0.0164‡			
350	2.45*	2.43	0.0148‡			
400	2.50*	2.49	0.0136‡			
500	2.56*	2.55	0.0116‡			
600	2.57*	2.56	0.0102‡			
700	2.59*	2.58	0.00914‡			
800	2.58*	2.57	0.00828‡			
900	2.54*	2.53	0.00757‡			
1000	2.50*	2.49	0.00698‡			
1200	2.40*	2.39	0.00605‡			
1333	2.35*					

† Uncertainties of the total thermal conductivity, k, are as follows:
0.50 Cu - 99.50 Au: ± 15% below 200 K and ± 10% above 200 K.

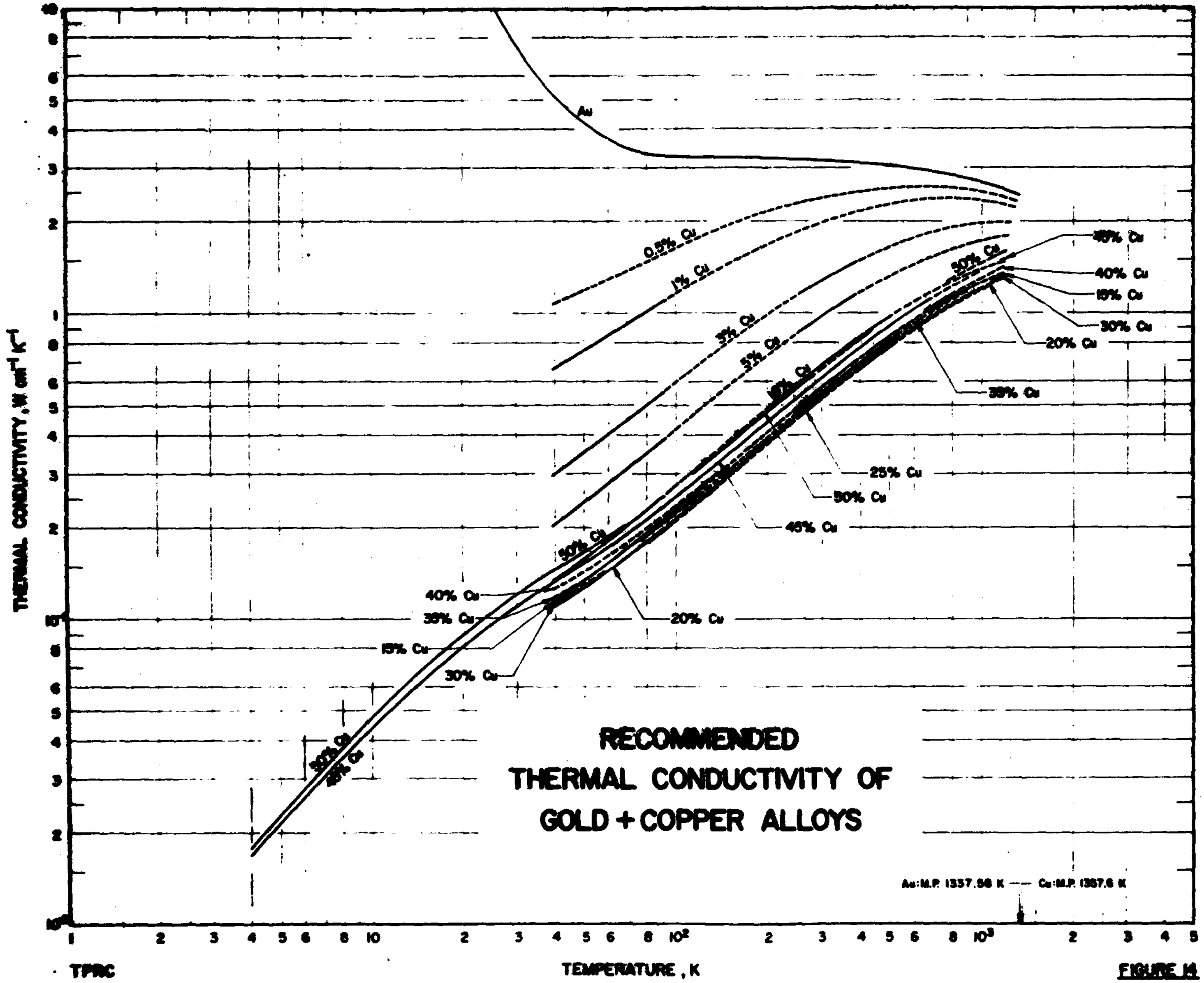
‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.



TPRC

FIGURE 13



TPRC

FIGURE 14

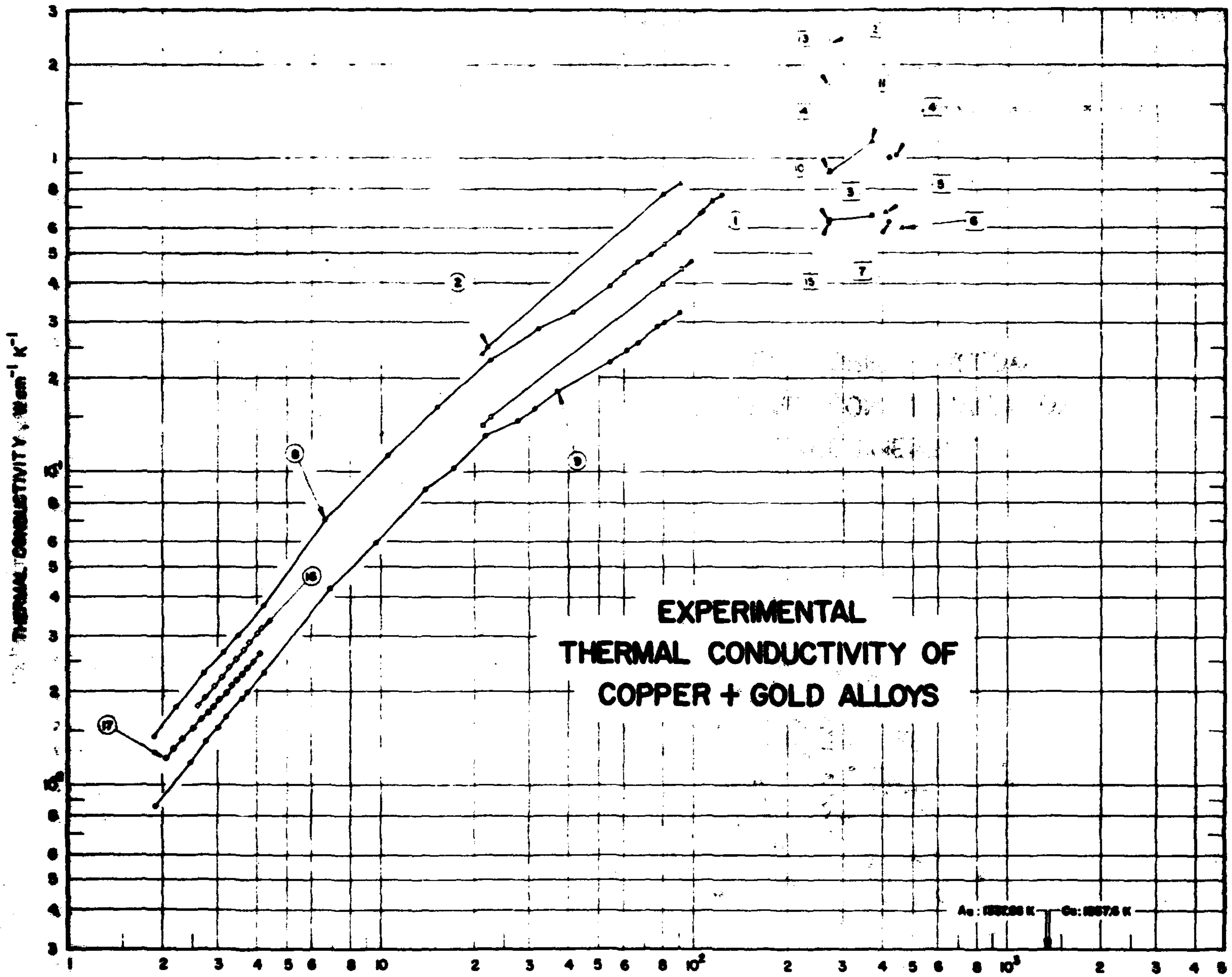

EXPERIMENTAL
THERMAL CONDUCTIVITY OF
COPPER + GOLD ALLOYS
THERMAL CONDUCTIVITY, W cm^{-1} K^{-1}
TEMPERATURE, K
TPRC

FIGURE 15

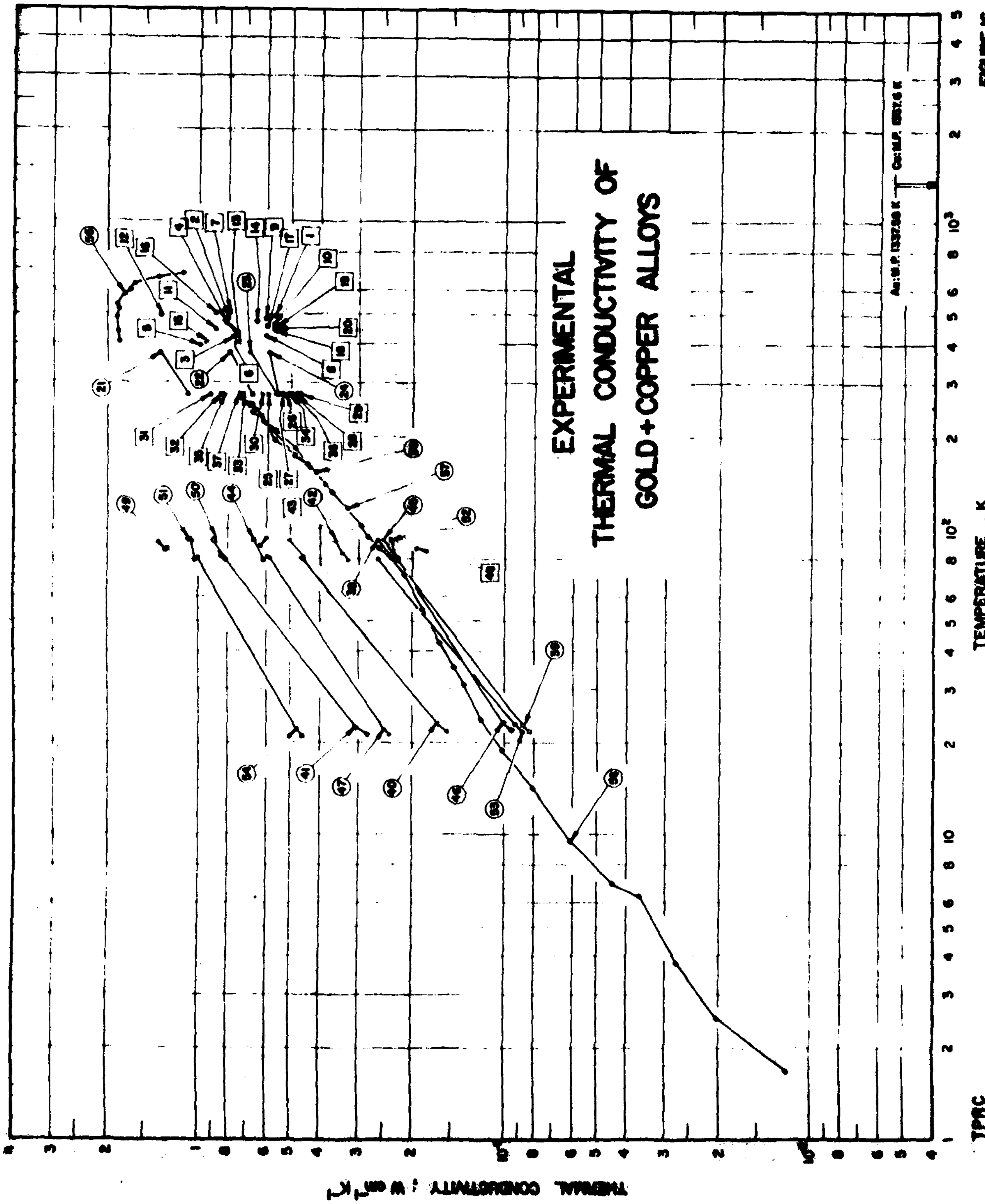

EXPERIMENTAL
THERMAL CONDUCTIVITY OF
GOLD + COPPER ALLOYS
TEMPERATURE , K
THERMAL CONDUCTIVITY , W cm⁻¹ K⁻¹
TPRC

FIGURE 16

TABLE 9. THERMAL CONDUCTIVITY OF COPPER - GOLD ALLOYS — SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Au	Composition (continued), Specifications, and Remarks
1	61	Grüneisen, E. and Reddemann, H.	1934	L	21-93	10	75.2	24.8	Calculated composition; polycrystalline; form factor 1.53 x 10^3; residual electrical resistivity 6.54 $\mu\Omega$ cm; electrical resistivity 5.09 and 4.71 $\mu\Omega$ cm at -190 and -251 C, respectively.
2	61	Grüneisen, E. and Reddemann, H.	1934	L	21-91	9	87.4	12.6	Calculated composition; polycrystalline; form factor 2.61 x 10^3; residual electrical resistivity 3.83 $\mu\Omega$ cm; electrical resistivity 2.487 and 2.172 $\mu\Omega$ cm at -190 and -251 C, respectively.
3	65	Zolotukhin, G.E.	1957	L	422.7		56.33	43.67	Calculated composition; cylindrical specimen 1.43 cm long and 0.63 cm^2 in cross-section; cast; density 14.30 g cm^{-3}.
4	65	Zolotukhin, G.E.	1957	L	448.2				The above specimen; annealed for 10 hr.
5	65	Zolotukhin, G.E.	1957	L	411.2				The above specimen; annealed for 20 hr.
6	65	Zolotukhin, G.E.	1957	L	467.2				The above specimen; annealed for 30 hr.
7	65	Zolotukhin, G.E.	1957	L	422.2				The above specimen; annealed for 40 hr.
8	62	Kemp, W.R.G., Klemens, P.G., and Tainsh, R.J.	1957	L	1.9-124			20.09	8 cm long and 0.5 cm in diameter; annealed at 750 C for 1 hr; electrical resistivity reported as 3.53, 3.91, and 5.37 $\mu\Omega$ cm at 0, 90, and 293 K, respectively.
9	62	Kemp, W.R.G., et al.	1957	L	1.9-91			37.99	Similar to the above specimen except electrical resistivity reported as 7.04, 7.38, and 8.89 $\mu\Omega$ cm at 0, 90, and 293 K, respectively.
10	63	Sedström, E.	1919	T	273, 373		55.24	44.76	Calculated composition; specimen rolled and drawn to wire 1 mm diameter; heated to near melting point for 0.5 hr; electrical conductivity 5.7 x 10^4 and 5.5 x 10^4 Ω^{-1} cm^{-1} at 0 and 100 C, respectively.
11	63	Sedström, E.	1919	T	273, 373		73.52	26.48	Similar to the above specimen except electrical conductivity 10.7 x 10^4 and 9.1 x 10^4 Ω^{-1} cm^{-1} at 0 and 100 C, respectively.
12	63	Sedström, E.	1924	T	273.2		94.6	5.4	Calculated composition; specimen rolled and drawn to a wire of 3 cm in length and 1 mm^2 in cross-section, then heated to the melting point; electrical resistivity 6.2 $\mu\Omega$ cm at 0 C.
13	63	Sedström, E.	1924	T	273.2		87.6	12.4	Similar to the above specimen except electrical resistivity 4.7 $\mu\Omega$ cm at 0 C.
14	63	Sedström, E.	1924	T	273.2		72.7	27.3	Similar to the above specimen except electrical resistivity 7.3 $\mu\Omega$ cm at 0 C.
15	63	Sedström, E.	1924	T	273.2		55.0	45.0	Similar to the above specimen except electrical resistivity 10.4 $\mu\Omega$ cm at 0 C.
16	120	Leaver, A.D.W. and Charsley, P.	1971	L	2.6-4.2	10 Au		25.4	Polycrystalline; obtained from the International Research and Development Co., Ltd.; annealed; residual electrical resistivity 4.386 $\mu\Omega$ cm.
17	120	Leaver, A.D.W. and Charsley, P.	1971	L	2.1-4.1	10 Au			The above specimen tensile strained 13.4% under a stress of 36.68 kg mm^{-2}; residual electrical resistivity 4.444 $\mu\Omega$ cm.

TABLE 10. THERMAL CONDUCTIVITY OF GOLD - COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
1	65	Zolotukhin, G. E.	1957	L	488.7	IV	75.61	24.39	Calculated composition; cast; 1.30 cm long and 0.63 cm^2 in cross-section; density 18.34 g cm^{-3}.
2	65	Zolotukhin, G. E.	1957	L	483.2	IV			The above specimen annealed 10 hr at 200 C.
3	65	Zolotukhin, G. E.	1957	L	420.7	IV			The above specimen annealed 20 hr at 200 C.
4	65	Zolotukhin, G. E.	1957	L	473.7	IV			The above specimen annealed 30 hr at 200 C.
5	65	Zolotukhin, G. E.	1957	L	395.2	IV			The above specimen annealed 40 hr at 200 C.
6	65	Zolotukhin, G. E.	1957	L	466.2	V	85.20	14.80	Calculated composition; cast; 1.30 cm long and 0.63 cm^2 in cross-section; density 19.40 g cm^{-3}.
7	65	Zolotukhin, G. E.	1957	L	504.7	V			The above specimen annealed 10 hr at 200 C.
8	65	Zolotukhin, G. E.	1957	L	426.2	V			The above specimen annealed 20 hr at 200 C.
9	65	Zolotukhin, G. E.	1957	L	481.7	V			The above specimen annealed 30 hr at 200 C.
10	65	Zolotukhin, G. E.	1957	L	460.7	V			The above specimen annealed 40 hr at 200 C.
11	65	Zolotukhin, G. E.	1957	L	445.7	II	50.82	49.18	Calculated composition; cast; 1.49 cm long and 0.63 cm^2 in cross-section; density 15.05 g cm^{-3}.
12	65	Zolotukhin, G. E.	1957	L	493.2	II			The above specimen annealed 10 hr at 200 C.
13	65	Zolotukhin, G. E.	1957	L	401.7	II			The above specimen annealed 20 hr at 200 C.
14	65	Zolotukhin, G. E.	1957	L	470.2	II			The above specimen annealed 30 hr at 200 C.
15	65	Zolotukhin, G. E.	1957	L	493.7	II			The above specimen annealed 40 hr at 200 C.
16	65	Zolotukhin, G. E.	1957	L	497.7	III	62.54	37.46	Calculated composition; cast; 1.45 cm long and 0.63 cm^2 in cross-section; density 16.70 g cm^{-3}.
17	65	Zolotukhin, G. E.	1957	L	455.7	III			The above specimen annealed 10 hr at 200 C.
18	65	Zolotukhin, G. E.	1957	L	437.7	III			The above specimen annealed 20 hr at 200 C.
19	65	Zolotukhin, G. E.	1957	L	457.7	III			The above specimen annealed 30 hr at 200 C.
20	65	Zolotukhin, G. E.	1957	L	444.7	III			The above specimen annealed 40 hr at 200 C.
21	63	Sedström, E.	1919	T	273, 373		96.73	3.27	Calculated composition; rolled and drawn to 1 mm diameter wire; annealed close to melting point for 0.5 hr; electrical conductivity 14.3 and 13.4 x $10^4 \Omega^{-1} cm^{-1}$ at 0 and 100 C, respectively.
22	63	Sedström, E.	1919	T	273, 373		92.55	7.45	Similar to the above specimen except electrical conductivity 8.5 and 8.2 x $10^4 \Omega^{-1} cm^{-1}$ at 0 and 100 C, respectively.
23	63	Sedström, E.	1919	T	273, 373		87.77	12.23	Similar to the above specimen except electrical conductivity 6.3 and 5.9 x $10^4 \Omega^{-1} cm^{-1}$ at 0 and 100 C, respectively.
24	63	Sedström, E.	1919	T	273, 373		59.25	40.75	Similar to the above specimen except electrical conductivity 5.0 and 4.6 x $10^4 \Omega^{-1} cm^{-1}$ at 0 and 100 C, respectively.
25	64	Sedström, E.	1924	T	273.2		50.8	49.2	Rolled and drawn to 1 mm^2 in cross-sectional area and 3 cm long; annealed close to melting point for 0.5 hr; electrical resistivity 10.8 $\mu\Omega$ cm at 273 K.
26	64	Sedström, E.	1924	T	273.2		54.0	46.0	Similar to the above specimen except electrical resistivity 11.4 $\mu\Omega$ cm at 273 K.

TABLE 10. THERMAL CONDUCTIVITY OF GOLD - COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
27	64	Sedström, E.	1924	T	273.2		57.0	43.0	Similar to the above specimen except electrical resistivity 11.8 μΩ cm at 273 K.
28	64	Sedström, E.	1924	T	273.2		62.6	37.4	Similar to the above specimen except electrical resistivity 13.0 μΩ cm at 273 K.
29	64	Sedström, E.	1924	T	273.2		67.2	32.8	Similar to the above specimen except electrical resistivity 13.6 μΩ cm at 273 K.
30	64	Sedström, E.	1924	T	273.2		71.9	28.1	Similar to the above specimen except electrical resistivity 10.5 μΩ cm at 273 K.
31	64	Sedström, E.	1924	T	273.2		78.1	21.9	Similar to the above specimen except electrical resistivity 7.6 μΩ cm at 273 K.
32	64	Sedström, E	1924	T	273.2		78.2	21.8	Similar to the above specimen except electrical resistivity 7.6 μΩ cm at 273 K.
33	64	Sedström, E.	1924	T	273.2		78.9	21.1	Similar to the above specimen except electrical resistivity 8.4 μΩ cm at 273 K.
34	64	Sedström, E.	1924	T	273.2		82.1	17.9	Similar to the above specimen except electrical resistivity 11.6 μΩ cm at 273 K.
35	64	Sedström, E.	1924	T	273.2		82.4	17.6	Similar to the above specimen except electrical resistivity 11.6 μΩ cm at 273 K.
36	64	Sedström, E.	1924	T	273.2		87.5	12.5	Similar to the above specimen except electrical resistivity 11.6 μΩ cm at 273 K.
37	64	Sedström, E.	1924	T	273.2		94.1	5.9	Similar to the above specimen except electrical resistivity 8.0 μΩ cm at 273 K.
38	61	Grüneisen, E. and Reddemann, H.	1934	L	80, 92	11	89.6	10.4	Calculated composition; polycrystalline; cast; electrical resistivity 9.27 μΩ cm at 83 K.
39	61	Grüneisen, E. and Reddemann, H.	1934	L	22-80	11a			The above specimen annealed in vacuo for 40 hr at 365 C; electrical resistivity 10.88 μΩ cm at 273 K.
40	61	Grüneisen, E. and Reddemann, H.	1934	L	22-91	12	96.9	3.10	Calculated composition; polycrystalline; cast; electrical resistivity 3.828, 4.345, and 5.94 μΩ cm at 22, 83, and 273 K, respectively.
41	61	Grüneisen, E. and Reddemann, H.	1934	L	21-91	13	98.43	1.57	Calculated composition; polycrystalline; cast; electrical resistivity 1.841, 2.353, and 3.93 μΩ cm at 22, 83, and 273 K, respectively.
42	61	Grüneisen, E. and Reddemann, H.	1934	L	79-91	14a	50.1	49.9	Calculated composition; polycrystalline; cast; quenched from 800 C; electrical resistivity 6.64 μΩ cm at 83 K.
43	61	Grüneisen, E. and Reddemann, H.	1934	L	87.4	14b			The above specimen annealed at ~400 C for 20 hr; electrical resistivity 3.23 and 5.80 μΩ cm at 83 and 273 K, respectively.
44	61	Grüneisen, E. and Reddemann, H.	1934	L	79, 92	14c			The above specimen annealed at ~360 C for 32 hr; electrical resistivity 3.126 and 5.42 μΩ cm at 83 and 273 K, respectively.
45	61	Grüneisen, E. and Reddemann, H.	1934	L	80, 92	14d			The above specimen annealed at ~620 C for 2 hr and then quenched; electrical resistivity 11.49 μΩ cm at 273 K.
46	61	Grüneisen, E. and Reddemann, H.	1934	L	22-80	14e			The above specimen measured after 5 months; electrical resistivity 9.88 and 11.48 μΩ cm at 83 and 273 K, respectively.

TABLE 10. THERMAL CONDUCTIVITY OF GOLD + COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
47	61	Grüneisen, E. and Reddemann, H.	1934	L	21-81	14f			The above specimen annealed at ~325 C for 30 hr; electrical resistivity 2.70 and 3.41 $\mu\Omega$ cm at 22 and 83 K, respectively.
48	61	Grüneisen, E. and Reddemann, H.	1934	L	86.9	15a	75.6	24.4	Calculated composition; polycrystalline; cast; quenched from 800 C; electrical resistivity 11.57, 13.2, and 13.41 $\mu\Omega$ cm at 83, 273, and 292 K, respectively.
49	61	Grüneisen, E. and Reddemann, H.	1934	L	85, 85	15b			The above specimen annealed at 360 C for 22 hr; electrical resistivity 1.753, 3.974, and 4.82 $\mu\Omega$ cm at 83, 273, and 293 K, respectively.
50	61	Grüneisen, E. and Reddemann, H.	1934	L	81, 92	15c			The above specimen annealed at 345 C for 30 hr; electrical resistivity 2.228 and 4.48 $\mu\Omega$ cm at 83 and 273 K, respectively.
51	61	Grüneisen, E. and Reddemann, H.	1934	L	79-91	15d			The above specimen annealed at 325 C for 30 hr; electrical resistivity 1.797 and 4.07 $\mu\Omega$ cm at 83 and 273 K, respectively.
52	61	Grüneisen, E. and Reddemann, H.	1934	L	79, 91	15e			The above specimen annealed at 800 C for 2 hr and then quenched; electrical resistivity 9.17 $\mu\Omega$ cm at 83 K.
53	61	Grüneisen, E. and Reddemann, H.	1934	L	22-79	15f			The above specimen measured after 4 months; electrical resistivity 7.90 $\mu\Omega$ cm at 83 K.
54	61	Grüneisen, E. and Reddemann, H.	1934	L	21-80	15g			The above specimen annealed at ~325 C for 30 hr; electrical resistivity 1.826 and 4.09 $\mu\Omega$ cm at 83 and 273 K, respectively.
55	126, 174, 175	Lindenbaum, S.D. and Quimby, S.L.	1962	L	407-680	Cu_3Au		49.18	Intermetallic compound; 0.1858 in. diameter and 2.41 in. long; successively annealed at 360 C for 90 hr, 240 C for 110 hr, and 220 C for 600 hr; critical temperature lies between 387.5 and 358.2 C; electrical resistivity reported as 4.2582, 4.3864, 4.8367, 5.2834, 5.6889, 6.2509, 6.6710, 7.2362, 8.2142, 9.3038, 10.6252, 10.8993, 11.3171, 12.1987, 13.6671, 14.0257, 14.0355, 14.0752, 14.1084, and 14.2959 $\mu\Omega$ cm at 33.30, 43.74, 83.38, 124.04, 160.92, 211.71, 246.80, 278.71, 311.98, 345.78, 373.61, 377.93, 382.60, 385.80, 387.54, 388.19, 390.97, 395.25, 404.20, and 419.77 C, respectively (selected from 76 points reported by the authors).
56	66	Goff, J.F., Verbalis, A.C., Rhyne, J.J., and Klemens, P.G.	1968	L	1.7-275	Cu_3Au		49.18	0.1 Fe; intermetallic compound; specimen 60 mm x 3.2 mm x 3.2 mm; prepared from ASARCO five-9 Cu and Au material; the melt was first homogenized by rocking for about 10 min then cast in a constricted end of the same tube; annealed for 2 hr at 850 C and quenched from 700 C by breaking the capsule in water (all melting and annealing the specimen and specimen materials were done in quartz tubes had been evacuated to less than 10^{-6} torr at close-off); residual electrical resistivity 0.092 $\mu\Omega$ cm; electrical resistivity ratio $\rho(300K)/\rho(4.2K) = 1.23$; electrical resistivity reported as 9.1, 9.1, 9.2, 9.3, 9.3, 9.2, 9.4, 9.4, 9.5, 9.7, 9.8, 9.9, 10.2, 10.5, 10.8, 11.0, 10.9, and 11.3 $\mu\Omega$ cm at 1.8, 5.6, 13.0, 16.4, 19.6, 30.0, 41.3, 63.2, 86.6, 101, 114, 131, 163, 191, 227, 254, 261, and 299 K respectively.

TABLE 10. THERMAL CONDUCTIVITY OF GOLD - COPPER ALLOYS — SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
57	66	Goff, J. F., Verbalis, A. C., Rhyne, J. J., and Klemens, P. G.	1968	L	117-269	Cu_3Au		49.18	Intermetallic compound; similar to the above except electrical resistivity reported as 9.7, 9.9, 10.1, 10.3, 10.4, 10.6, 10.8, 10.7, 10.9, and 11.3 $\mu\Omega$ cm at 88, 115, 148, 159, 180, 194, 224, 232, 247, and 293 K, respectively; measurement was made with an insulating packing inside the radiation shield.
58	66	Goff, J. F., et al.	1968	L	154-276	Cu_3Au		49.18	Similar to the above except electrical resistivity reported as 9.1, 9.9, 9.8, 9.9, 10.1, 10.5, 11.0, 10.7, 10.9, 11.0, and 11.4 $\mu\Omega$ cm at 9.0, 112, 129, 143, 171, 211, 235, 240, 260, 265, and 287 K, respectively; measurement was made in the original condition but with a measured radiation loss correction.

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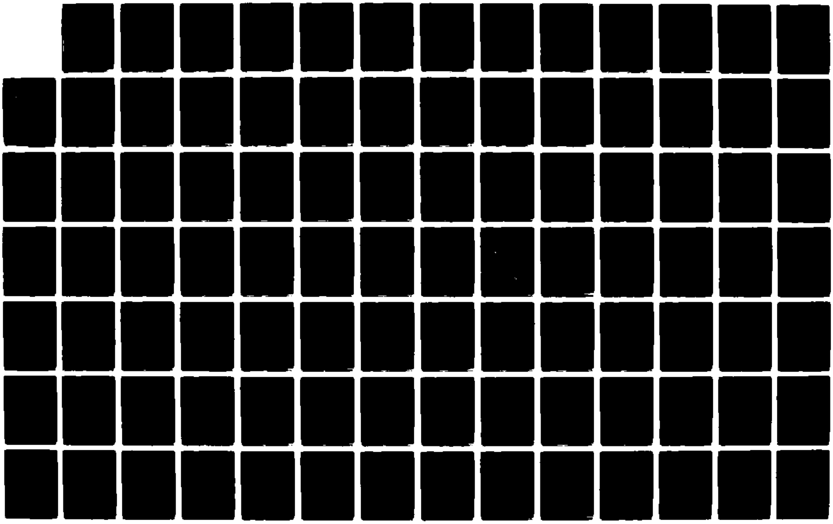

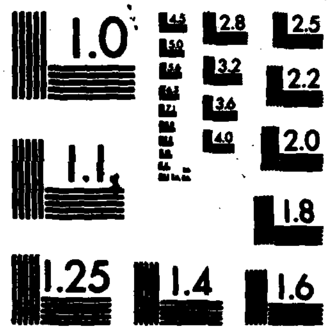

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4.4. Copper-Nickel Alloy System

The copper-nickel alloy system forms a continuous series of solid solutions and is free of all transformations except that of ferromagnetism. As shown in Figure 2, the electrical resistivity versus temperature curves for Ni + Cu alloys change slope abruptly at the Curie temperature of the alloys. The Curie temperature decreases as the concentration of copper in the alloys increases. The ferromagnetism disappears and the Curie temperature drops to zero as the concentration of copper reaches 61.88% (60 At.%).

Mott [3] has given an explanation of the ferromagnetic behavior of these alloys based on the filling of holes in the d band of nickel by the s electrons of copper. The d-shell in a copper atom is completely occupied and there is a single s electron outside, whereas the $3d\uparrow$ band of a nickel atom is full but there are 0.54 holes in the $3d\downarrow$ band; these d-band holes are the elementary magnets in nickel. The Curie temperature is proportional to the number of elementary magnets per unit volume, which in nickel is thus 0.54 times the number of atoms per unit volume. The density of states in the d band of nickel atom at the Fermi surface is approximately ten times greater than the density of states in the s band, so that as copper is added to nickel about 90 percent of the extra s electrons go to fill up the d band, and thus decrease the number of elementary magnets per unit volume, until at 60 At.% Cu the d band of nickel is full, at which point the ferromagnetism disappears and the Curie temperature drops to 0 K. The insert in Figure 2 shows the Curie temperature as a function of percent copper in nickel, which is linear for the atomic percent of copper. This straight-line relationship was determined from the electrical resistivity data shown in Figure 2. The behavior of the electrical resistivity of these alloys has a direct bearing on the behavior of the thermal conductivity (see Figure 18), and therefore the knowledge of the former is prerequisite to the understanding of the latter.

There are 153 sets of experimental data available for the thermal conductivity of this alloy system. However, of the 104 data sets available for Cu + Ni alloys listed in Table 12 and shown in Figure 19, 27 sets are merely single data points and 25 sets cover only a narrow temperature range from around room temperature to about 500 K. Of the 49 data sets for Ni + Cu alloys listed in Table 13 and shown in Figure 20, 23 sets are single data points. Furthermore, many sets of data show large discrepancies.

For the Cu + Ni alloys, the most reliable measurements at room temperature were made by Smith and Palmer [49] (Cu + Ni curves 1-7), surprisingly in 1935, for a set of well-annealed alloys. Electrical resistivity data were also reported for the same specimens used for the thermal conductivity measurements. These provided the basis for the easy separation of the lattice component from the measured thermal conductivity.

Hulm [69] measured the thermal conductivity of an alloy with 20% Ni below 25 K (Cu + Ni curve 15). Berman [70] measured thermal conductivity of a sample of Constantan

(40% Ni) below 100 K (Cu + Ni curve 21). Wilkinson and Wilks [71] measured the thermal conductivity of an alloy with 30% Ni below 20 K (Cu + Ni curve 14). These three sets of low-temperature data appear to be reliable and consistent in view of the cold-work condition of the 30% Ni specimen of Wilkinson and Wilks (curve 14).

In the temperature range below 70 K, Erdmann and Jahoda have measured the thermal conductivity of the Cu-Ni alloy system several times [72-74] (Cu + Ni curves 52-55, 62-66, 68, and 84; Ni + Cu curves 13-19 and 21-23). One set of their measurements [74] (Cu + Ni curves 52-55 and Ni + Cu curves 13-19) is the only one that covers a wide range of composition at low temperature. However, it was very difficult to evaluate the reliability of their results. For copper-rich alloys, the lattice thermal conductivities derived from their measured total thermal conductivities are about 40% higher than those derived from other authors' results. Since their samples seemed to be the best annealed (at 930 C) among the alloy samples, it had been thought that the lattice thermal conductivities of their samples might be higher than those of the others because annealing could eliminate dislocations. However, after the effect of annealing on the electrical resistivity and lattice thermal conductivity of binary alloys had been reviewed carefully, it was concluded that the differences are too large to be accounted for by annealing. Furthermore, around liquid helium temperature, the difference between the lattice thermal conductivities of their own dilute and concentrated alloys are too large compared with those of other measurements. If their measured total thermal conductivities are connected to the total thermal conductivities above 300 K measured by other authors, the slopes of the conductivity-temperature curves become negative between 100 and 300 K for concentrated alloys. This seems unlikely as it does not occur in the conductivity-temperature curves of the analogous silver-palladium alloys. Recent private communication from Klemens [76] provided useful thermal conductivity data for a copper alloy with 4 At.% Ni at temperatures below 40 K (Cu + Ni curve 103). The sample was annealed at 1075 C for 72 hours and slowly cooled. The results also indicate that the lattice thermal conductivities of Erdmann and Jahoda are too high. Consequently, the results of Erdmann and Jahoda were not used in the present data synthesis.

For Ni + Cu alloys, Sager [77] (Ni + Cu curves 1 and 2), Smith [45] (Ni + Cu curves 3-6), and Sedström [63] (Ni + Cu curves 7 and 8) have measured the thermal conductivity around room temperature. There is some doubt about the reported compositions of their specimens as the electrical resistivity data reported for the same specimens differ from those obtained by other authors for alloys with the same nominal compositions.

Greig and Harrison [78] measured the thermal conductivities of nickel alloys with 0.32, 0.6, 1.5, and 4.2 At.% Cu below 100 K (Ni + Cu curves 9-12). More recently Farrell and Greig [79] studied the electrical resistivity and thermal conductivity of a nickel alloy with 0.31 At.% Cu below 100 K (Ni + Cu curve 34). They concluded that the lattice thermal conductivity of pure nickel is quite high and close to those of dilute copper alloys.

Chari [80] has suggested a method to separate the lattice thermal conductivity from total thermal conductivity of pure nickel and dilute nickel-rhenium alloys above 400 K. There is, however, doubt concerning his method of graphical separation of electrical resistivity into the intrinsic and magnetic components, because the anomaly of the temperature dependence of the electrical resistivity of the ferromagnetic metals can be explained by the ferromagnetic ordering of metals below the Curie point. Many authors have tried to express the resistivities of the ferromagnetic alloys in the form of $\rho = \rho^{*} (1 + \mu)$, where μ, the ferromagnetic ordering parameter, is negative and vanishes above the Curie point [167], and ρ^{*} represents the resistivity of ferromagnetic metal in the absence of ferromagnetic ordering. In other words, ρ^{*} represents the resistivity of the "normal" non-ferromagnetic metal. Farrell and Greig [81] indicated that deviations from Matthiessen's rule due to spin mixing must be taken into account when analyzing the electronic transport properties of nickel alloys.

In the present data synthesis, the electronic thermal conductivities of the alloys for which both thermal conductivity and electrical resistivity were reported were calculated from eq. (12) in order to separate the lattice component from the measured total thermal conductivity. The resulting "experimental" lattice thermal conductivity data were then used for the adjustment of the lattice thermal conductivities of the virtual crystals so that the k_g values calculated from eq. (35) at moderate and high temperatures are in agreement with the experimental data. At low temperatures the lattice thermal conductivity values were obtained from the experimental data similarly as the difference of the measured k and the calculated k_e. The recommended total thermal conductivity values at low temperatures are in agreement with the data of Greig and Harrison [78] (Ni + Cu curves 9-12), Zimmerman [130] (Cu + Ni curves 17 and 20), Berman [70] (Cu + Ni curve 21), and Bouley, et al. [76] (Ni + Cu curve 104) to within 12%, and those at higher temperatures are in agreement with the data of Smith and Palmer [49] (Cu + Ni curves 1-7 and 85-90), Mikryukov [136] (Cu + Ni curve 44), Mikryukov [144] (Cu + Ni curves 71-73), Willett [146] (Cu + Ni curves 98-102), and Smith [45] (Ni + Cu curves 3-6) to within 10%.

The resulting recommended values for k, k_e, and k_g are tabulated in Table 11 for 25 alloy compositions covering the temperatures from 4 to 1200 K. These values are for well-annealed alloys. The values for k are also shown in Figures 17 and 18. The values of residual electrical resistivity for the alloys are also given in Table 11. The uncertainties of the thermal conductivity values are stated in a footnote to Table 11, while the uncertainties of the k_e and k_g values are indicated by their being designated as recommended, provisional, or typical values. The ranges of uncertainties of recommended, provisional, and typical values are less than ±15%, between ±15 and ±30%, and greater than ±30%, respectively.

TABLE 11. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-NICKEL ALLOY SYSTEM†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 99.50% (99.46 At.%) Ni: 0.50% (0.54 At.%)				Cu: 99.00% (98.92 At.%) Ni: 1.00% (1.08 At.%)				Cu: 97.00% (96.76 At.%) Ni: 3.00% (3.24 At.%)				Cu: 95.00% (94.61 At.%) Ni: 5.00% (5.39 At.%)			
ρ_0 = 0.620 μΩ cm				ρ_0 = 1.25 μΩ cm				ρ_0 = 3.70 μΩ cm				ρ_0 = 6.10 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.170*	0.158	0.0128§	4	0.0917	0.0782	0.0135‡	4	0.0347	0.0264	0.00830	4	0.0215	0.0160	0.00550
6	0.281*	0.236	0.0450§	6	0.150	0.117	0.0335‡	6	0.0611	0.0396	0.0215	6	0.0391	0.0240	0.0151
8	0.380*	0.315	0.0649§	8	0.218	0.156	0.0625‡	8	0.0936	0.0528	0.0408	8	0.0616	0.0320	0.0296
10	0.525*	0.394	0.131§	10	0.295	0.195	0.100‡	10	0.132	0.0660	0.0655	10	0.0890	0.0400	0.0490
15	0.646*	0.391	0.255§	15	0.496	0.293	0.203‡	15	0.234	0.0990	0.135	15	0.166	0.0601	0.106
20	1.14*	0.780	0.356§	20	0.684	0.391	0.293‡	20	0.340	0.132	0.208	20	0.250	0.0801	0.170
25	1.38*	0.945	0.430§	25	0.840	0.482	0.358‡	25	0.428	0.164	0.264	25	0.321	0.0999	0.221
30	1.59*	1.11	0.480§	30	0.978	0.573	0.405‡	30	0.498	0.196	0.302	30	0.379	0.120	0.259
40	1.92*	1.39	0.535§	40	1.20	0.743	0.460‡	40	0.599	0.258	0.341	40	0.458	0.158	0.300
50	2.14*	1.60	0.545§	50	1.36	0.889	0.470‡	50	0.666	0.315	0.351	50	0.509	0.195	0.314
60	2.26*	1.73	0.535§	60	1.46	1.00	0.465‡	60	0.715	0.366	0.349	60	0.544	0.231	0.313
70	2.32*	1.82	0.500§	70	1.54	1.10	0.445‡	70	0.755	0.414	0.341	70	0.571	0.264	0.307
80	2.36*	1.89	0.465	80	1.61	1.19	0.420	80	0.790	0.459	0.331	80	0.593	0.296	0.297
90	2.39*	1.96	0.430	90	1.66*	1.27	0.395	90	0.823*	0.504	0.319	90	0.615*	0.328	0.287
100	2.43*	2.03	0.400	100	1.72*	1.35	0.370	100	0.854*	0.548	0.306	100	0.634*	0.358	0.276
150	2.64*	2.35	0.293	150	1.98*	1.70	0.281	150	1.01*	0.759	0.248	150	0.731*	0.505	0.226
200	2.82*	2.58	0.234	200	2.20*	1.97	0.227	200	1.15*	0.947	0.204	200	0.828*	0.640	0.188
250	2.93*	2.74	0.194	250	2.36*	2.17	0.189	250	1.29*	1.11	0.172	250	0.922*	0.761	0.160
273	2.97	2.79	0.179	273	2.41*	2.24	0.175	273	1.34*	1.18	0.161	273	0.963*	0.813	0.150
300	3.04	2.87	0.164	300	2.49	2.32	0.161	300	1.41	1.26	0.149	300	1.01	0.872	0.140
350	3.10	2.96	0.143	350	2.59	2.45	0.140	350	1.51	1.38	0.131	350	1.09	0.972	0.123
400	3.16	3.04	0.126	400	2.68	2.56	0.124	400	1.61	1.49	0.116	400	1.17	1.06	0.110
500	3.24*	3.13	0.102	500	2.80	2.70	0.100	500	1.77*	1.67	0.0953	500	1.32	1.23	0.0911
600	3.26*	3.18	0.0853	600	2.90	2.81	0.0843	600	1.90*	1.82	0.0807	600	1.45	1.37	0.0776
700	3.28*	3.21	0.0734	700	2.96	2.89	0.0727	700	2.01*	1.94	0.0699	700	1.56	1.49	0.0675
800	3.27*	3.21	0.0644	800	2.98	2.92	0.0638	800	2.08*	2.02	0.0617	800	1.65	1.59	0.0598
900	3.26*	3.20	0.0574	900	2.98	2.92	0.0569	900	2.14*	2.09	0.0552	900	1.72	1.66	0.0536
1000	3.22*	3.17	0.0517	1000	2.96	2.91	0.0513	1000	2.18*	2.13	0.0499	1000	1.77	1.72	0.0486
1100	3.20*	3.15	0.0471	1100	2.96*	2.91	0.0468	1100	2.22*	2.17	0.0455	1100	1.82	1.78	0.0445
1200	3.16*	3.12	0.0432	1200	2.94*	2.89	0.0429	1200	2.23*	2.19	0.0419	1200	1.86	1.82	0.0410

† Uncertainties of the total thermal conductivity, k, are as follows:
99.50 Cu - 0.50 Ni: ± 10% below 200 K and ± 5% above 200 K.
99.00 Cu - 1.00 Ni: ± 10% below 200 K and ± 5% above 200 K.
97.00 Cu - 3.00 Ni: ± 5%.
95.00 Cu - 5.00 Ni: ± 5%.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 11. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 90.00% (89.27 At.%) Ni: 10.00% (10.73 At.%)				Cu: 85.00% (83.96 At.%) Ni: 15.00% (16.04 At.%)				Cu: 80.00% (78.71 At.%) Ni: 20.00% (21.29 At.%)				Cu: 75.00% (73.49 At.%) Ni: 25.00% (26.51 At.%)			
ρ_0 = 12.15 μΩ cm				ρ_0 = 17.95 μΩ cm				ρ_0 = 23.70 μΩ cm				ρ_0 = 29.30 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0112	0.00804	0.00315	4	0.00869*‡	0.00544	0.00325‡	4	0.00762‡	0.00412	0.00350‡	4	0.00734‡	[illegible]	0.00390‡
6	0.0216	0.0121	0.00950	6	0.0170*‡	0.00817	0.00890‡	6	0.0153‡	0.00619	0.00910‡	6	0.0143*‡	0.00500	0.00930‡
8	0.0358	0.0161	0.0197	8	0.0283*‡	0.0109	0.0175‡	8	0.0253‡	0.00825	0.0170‡	8	0.0234*‡	0.00667	0.0167‡
10	0.0636	0.0301	0.0335	10	0.0426*‡	0.0136	0.0290‡	10	0.0373‡	0.0103	0.0270‡	10	0.0343*‡	0.00834	0.0260‡
15	0.106	0.0302	0.0760	15	0.0839*‡	0.0204	0.0635‡	15	0.0725‡	0.0155	0.0570‡	15	0.0660*‡	0.0125	0.0535‡
20	0.164	0.0402	0.124	20	0.128*‡	0.0272	0.101‡	20	0.111‡	0.0206	0.0900‡	20	0.100*‡	0.0167	0.0835‡
25	0.215	0.0502	0.165	25	0.169*‡	0.0339	0.135‡	25	0.144‡	0.0257	0.118‡	25	0.129*‡	0.0209	0.108‡
30	0.256	0.0601	0.196	30	0.202*‡	0.0407	0.161‡	30	0.172‡	0.0309	0.141‡	30	0.152*‡	0.0251	0.127‡
40	0.316	0.0790	0.236	40	0.252*‡	0.0541	0.198‡	40	0.215‡	0.0411	0.174‡	40	0.189*‡	0.0334	0.155‡
50	0.365	0.0986	0.265	50	0.284*‡	0.0673	0.217‡	50	0.243‡	0.0512	0.192‡	50	0.212*‡	0.0416	0.170‡
60	0.378	0.118	0.260	60	0.305*‡	0.0802	0.225‡	60	0.261‡	0.0611	0.200‡	60	0.229*‡	0.0496	0.180‡
70	0.396	0.137	0.258	70	0.317*‡	0.0931	0.224‡	70	0.273‡	0.0711	0.202‡	70	0.241*‡	0.0579	0.183‡
80	0.407	0.156	0.252	80	0.327	0.106	0.221	80	0.281‡	0.0808	0.200‡	80	0.248*‡	0.0656	0.182‡
90	0.416*	0.174	0.242	90	0.333*	0.118	0.215	90	0.286*	0.0904	0.196	90	0.253*	0.0738	0.179
100	0.423*	0.190	0.233	100	0.339*	0.130	0.209	100	0.290*	0.0994	0.191	100	0.257*	0.0808	0.176
150	0.468*	0.275	0.193	150	0.363*	0.189	0.174	150	0.306*	0.144	0.162	150	0.270*	0.117	0.153
200	0.536*	0.353	0.183	200	0.392*	0.244	0.148	200	0.324*	0.187	0.138	200	0.283*	0.152	0.131
250	[illegible]*	0.428	0.141	250	0.427*	0.299	0.128	250	0.348*	0.228	0.120	250	0.300*	0.186	0.114
273	[illegible]	0.460	0.132	273	0.444*	0.323	0.121	273	0.361	0.247	0.113	273	0.309*	0.201	0.108
300	0.621	0.498	0.124	300	0.464	0.350	0.113	300	0.375	0.269	0.106	300	0.320*	0.218	0.101
350	0.676	0.566	0.110	350	0.502	0.400	0.102	350	0.403	0.308	0.0957	350	0.341*	0.260	0.0813
400	0.727	0.637	0.0896	400	0.540	0.448	0.0922	400	0.432	0.345	0.0870	400	0.364*	0.281	0.0832
500	0.831	0.747	0.0833	500	0.615*	0.537	0.0778	500	0.491	0.417	0.0736	500	0.413*	0.343	0.0703
600	0.930	0.860	0.0716	600	0.684*	0.617	0.0673	600	0.548	0.483	0.0641	600	0.462*	0.400	0.0617
700	1.01	0.940	0.0636	700	0.753*	0.694	0.0594	700	0.601	0.544	0.0568	700	0.511*	0.455	0.0548
800	1.09	1.03	0.0590	800	0.820*	0.767	0.0531	800	0.654	0.603	0.0509	800	0.557*	0.508	0.0492
900	1.15	1.11	0.0595	900	0.879*	0.839	0.0481	900	0.708	0.662	0.0462	900	0.601*	0.556	0.0446
1000	1.22	1.16	0.0480	1000	0.937*	0.894	0.0439	1000	0.756	0.714	0.0423	1000	0.642*	0.601	0.0411
1100	1.28*	1.24	0.0422	1100	0.988*	0.948	0.0404	1100	0.804*	0.765	0.0390	1100	0.683*	0.645	0.0379
1200	1.33*	1.29	0.0390	1200	1.04*	1.00	0.0375	1200	0.851*	0.814	0.0362	1200	0.723*	0.686	0.0362

† Uncertainties of the total thermal conductivity, k, are as follows:
90.00 Cu - 10.00 Ni: ± 5%.
85.00 Cu - 15.00 Ni: ± 15% below 80 K, ± 10% between 80 and 200 K, and ± 5% above 200 K.
80.00 Cu - 20.00 Ni: ± 15% below 80 K, ± 10% between 80 and 200 K, and ± 5% above 200 K.
75.00 Cu - 25.00 Ni: ± 15% below 80 K, ± 10% between 80 and 200 K, and ± 5% above 200 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 11. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 70.00% (68.31 At.%) Ni: 30.00% (31.69 At.%)			
ρ_o = 34.90 μΩ cm			
T	k	k_e	k_g
4	0.00726‡	0.00280	0.00446‡
6	0.0142‡	0.00420	0.0100‡
8	0.0231‡	0.00560	0.0175‡
10	0.0335‡	0.00700	0.0265‡
15	0.0620‡	0.0105	0.0515‡
20	0.0930‡	0.0140	0.0790‡
25	0.118‡	0.0175	0.100‡
30	0.139‡	0.0210	0.118‡
40	0.170‡	0.0280	0.142‡
50	0.192‡	0.0350	0.157‡
60	0.207‡	0.0418	0.165‡
70	0.217‡	0.0486	0.168‡
80	0.223‡	0.0554	0.168‡
90	0.229*	0.0621	0.166
100	0.243*	0.0679	0.164
150	0.245*	0.0961	0.144
200	0.255*	0.129	0.125
250	0.265*	0.156	0.119
273	0.275*	0.171	0.104
300	0.284	0.186	0.0977
350	0.305	0.214	0.0901
400	0.325	0.241	0.0844
500	0.360	0.294	0.0666
600	0.407	0.347	0.0600
700	0.455	0.397	0.0582
800	0.491	0.443	0.0480
900	0.532	0.485	0.0437
1000	0.570	0.530	0.0401
1100	0.604*	0.566	0.0371
1200	0.640*	0.606	0.0345

Cu: 65.00% (63.18 At.%) Ni: 35.00% (36.82 At.%)			
ρ_o = 40.05 μΩ cm			
T	k	k_e	k_g
4	0.00749*‡	0.00244	0.00505‡
6	0.0145*‡	0.00366	0.0108‡
8	0.0232*‡	0.00488	0.0183‡
10	0.0331*‡	0.00610	0.0270‡
15	0.0602*‡	0.00915	0.0510‡
20	0.0877*‡	0.0122	0.0755‡
25	0.110*‡	0.0154	0.0950‡
30	0.128*‡	0.0185	0.110‡
40	0.157*‡	0.0246	0.132‡
50	0.177*‡	0.0307	0.146‡
60	0.191*‡	0.0367	0.154‡
70	0.199*‡	0.0428	0.156‡
80	0.206*‡	0.0488	0.157‡
90	0.211*	0.0547	0.156
100	0.214*	0.0598	0.154
150	0.225*	0.0871	0.138
200	0.235*	0.113	0.122
250	0.246*	0.139	0.107
273	0.252*	0.151	0.101
300	0.260*	0.165	0.0950
350	0.276*	0.190	0.0858
400	0.293*	0.215	0.0783
500	0.330*	0.263	0.0669
600	0.368*	0.310	0.0585
700	0.408*	0.356	0.0521
800	0.446*	0.399	0.0470
900	0.480*	0.438	0.0428
1000	0.515*	0.475	0.0393
1100	0.548*	0.512	0.0364
1200	0.581*	0.548	0.0339

Cu: 60.00% (58.09 At.%) Ni: 40.00% (41.91 At.%)			
ρ_o = 45.00 μΩ cm			
T	k	k_e	k_g
4	0.00797‡	0.00217	0.00580‡
6	0.0152‡	0.00326	0.0119‡
8	0.0238‡	0.00434	0.0195‡
10	0.0334‡	0.00543	0.0280‡
15	0.0586‡	0.00814	0.0505‡
20	0.0839‡	0.0109	0.0730‡
25	0.104‡	0.0137	0.0900‡
30	0.121‡	0.0164	0.105‡
40	0.147‡	0.0219	0.125‡
50	0.164‡	0.0274	0.137‡
60	0.178‡	0.0329	0.145‡
70	0.185‡	0.0383	0.147‡
80	0.192‡	0.0437	0.148‡
90	0.196‡	0.0491	0.147‡
100	0.200*	0.0536	0.146
150	0.212*	0.0786	0.133
200	0.221*	0.103	0.118
250	0.231*	0.127	0.104
273	0.237*	0.138	0.0989
300	0.244	0.151	0.0931
350	0.258	0.174	0.0842
400	0.274	0.198	0.0760
500	0.309	0.244	0.0657
600	0.347	0.289	0.0575
700	0.384	0.333	0.0512
800	0.419	0.373	0.0462
900	0.453	0.411	0.0421
1000	0.485	0.447	0.0387
1100	0.517	0.481	0.0359
1200	0.547	0.514	0.0334

Cu: 55.00% (53.04 At.%) Ni: 45.00% (46.96 At.%)			
ρ_o = 46.60 μΩ cm			
T	k	k_e	k_g
4	0.00900*‡	0.00210	0.00690‡
6	0.0166*‡	0.00315	0.0134‡
8	0.0253*‡	0.00419	0.0211‡
10	0.0347*‡	0.00524	0.0295‡
15	0.0589*‡	0.00786	0.0510‡
20	0.0820*‡	0.0105	0.0715‡
25	0.101‡	0.0129‡	0.0885‡
30	0.118‡	0.0155‡	0.102‡
40	0.142‡	0.0206‡	0.121‡
50	0.159‡	0.0257‡	0.133‡
60	0.170‡	0.0308‡	0.139‡
70	0.178‡	0.0359‡	0.142‡
80	0.184	0.0408	0.143
90	0.189	0.0459	0.143
100	0.192	0.0502	0.142
150	0.204	0.0738	0.130
200	0.213	0.0966	0.116
250	0.222	0.119	0.103
273	0.227	0.129	0.0976
300	0.233	0.141	0.0919
350	0.246	0.163	0.0831
400	0.261*	0.186	0.0750
500	0.295*	0.230	0.0649
600	0.332*	0.275	0.0569
700	0.370*	0.319	0.0507
800	0.404*	0.358	0.0457
900	0.437*	0.396	0.0417
1000	0.469*	0.431	0.0383
1100	0.501*	0.466	0.0355
1200	0.533*	0.500	0.0331

† Uncertainties of the total thermal conductivity, k, are as follows:
70.00 Cu - 30.00 Ni: ± 15% below 80 K, ± 10% between 80 and 200 K, and ± 5% above 200 K.
65.00 Cu - 35.00 Ni: ± 15% below 80 K, ± 10% between 80 and 200 K, and ± 5% above 200 K.
60.00 Cu - 40.00 Ni: ± 15% below 90 K, ± 10% between 90 and 200 K, and ± 5% above 200 K.
55.00 Cu - 45.00 Ni: ± 15% below 80 K, ± 10% between 70 and 200 K, and ± 5% above 200 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 11. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 50.00% (48.62 At.%) Ni: 50.00% (51.38 At.%); ρ_0 = 40.30 μΩ cm			
T	k	k_e	k_g
4	0.0107‡	0.00243	0.00825‡
6	0.0186‡	0.00364	0.0150‡
8	0.0274‡	0.00485	0.0226‡
10	0.0371‡	0.00606	0.0310‡
15	0.0606‡	0.00909	0.0515‡
20	0.0831‡	0.0121	0.0710‡
25	0.101‡	0.0144‡	0.0870‡
30	0.117‡	0.0171‡	0.0995‡
40	0.139‡	0.0223‡	0.117‡
50	0.156‡	0.0275‡	0.128‡
60	0.167‡	0.0324‡	0.135‡
70	0.175‡	0.0373‡	0.138‡
80	0.182	0.0421‡	0.140
90	0.187*	0.0468‡	0.140
100	0.190*	0.0507‡	0.139
150	0.201*	0.0729	0.128
200	0.208*	0.0944	0.114
250	0.217*	0.115	0.102
273	0.231*	0.134	0.0970
300	0.227	0.136	0.0913
350	0.239	0.156	0.0836
400	0.254*	0.178	0.0754
500	0.287*	0.222	0.0645
600	0.323*	0.266	0.0565
700	0.361*	0.311	0.0503
800	0.396*	0.350	0.0454
900	0.430*	0.389	0.414
1000	0.462*	0.424	0.0381
1100	0.493*	0.458	0.0353
1200	0.525*	0.492	0.0328

Cu: 45.00% (43.05 At.%) Ni: 55.00% (56.95 At.%); ρ_0 = 35.85 μΩ cm			
T	k	k_e	k_g
4	0.0120*‡	0.00273	0.00930‡
6	0.0243*‡	0.00469	0.0161‡
8	0.0292*‡	0.00545	0.0237‡
10	0.0385*‡	0.00682	0.0317‡
15	0.0617*‡	0.0102	0.0515‡
20	0.0842*‡	0.0137	0.0705‡
25	0.102*‡	0.0163‡	0.0860‡
30	0.118*‡	0.0194‡	0.0990‡
40	0.143*‡	0.0255‡	0.117‡
50	0.159*‡	0.0312‡	0.128‡
60	0.172*‡	0.0368‡	0.135‡
70	0.181*‡	0.0421‡	0.139‡
80	0.188*‡	0.0469‡	0.141‡
90	0.194*‡	0.0522‡	0.142‡
100	0.197*‡	0.0562‡	0.141‡
150	0.209*‡	0.0775‡	0.131‡
200	0.214*	0.0969	0.117
250	0.219*	0.116	0.102
273	0.222*	0.125	0.0970
300	0.227*	0.136	0.0913
350	0.239*	0.156	0.0825
400	0.252*	0.177	0.0754
500	0.284*	0.220	0.0644
600	0.319*	0.263	0.0564
700	0.357*	0.307	0.0502
800	0.392*	0.347	0.0453
900	0.426*	0.385	0.0413
1000	0.459*	0.421	0.0380
1100	0.491*	0.456	0.0352
1200	0.522*	0.489	0.0327

Cu: 40.00% (39.12 At.%) Ni: 60.00% (61.88 At.%); ρ_0 = 31.60 μΩ cm			
T	k	k_e	k_g
4	0.0131*‡	0.00309	0.0100‡
6	0.0216*‡	0.00464	0.0170‡
8	0.0307*‡	0.00619	0.0245‡
10	0.0402*‡	0.00773	0.0325‡
15	0.0631*‡	0.0116	0.0515‡
20	0.0860*‡	0.0155	0.0705‡
25	0.105*‡	0.0188‡	0.0860‡
30	0.121*‡	0.0224‡	0.0990‡
40	0.147*‡	0.0294‡	0.118‡
50	0.166*‡	0.0361‡	0.130‡
60	0.180*‡	0.0425‡	0.137‡
70	0.190*‡	0.0487‡	0.141‡
80	0.198	0.0545‡	0.143‡
90	0.204*‡	0.0600‡	0.144‡
100	0.208*‡	0.0645‡	0.143‡
150	0.219*‡	0.0868‡	0.132‡
200	0.223*‡	0.105‡	0.118
250	0.224*	0.121	0.103
273	0.228	0.130	0.0976
300	0.232	0.140	0.0919
350	0.243	0.160	0.0830
400	0.255	0.179	0.0758
500	0.284	0.219	0.0647
600	0.318	0.262	0.0566
700	0.356	0.306	0.0504
800	0.391	0.345	0.0454
900	0.424	0.383	0.0414
1000	0.458	0.420	0.0380
1100	0.491*	0.456	0.0352
1200	0.525*	0.493	0.0328

Cu: 35.00% (33.22 At.%) Ni: 65.00% (66.78 At.%); ρ_0 = 27.65 μΩ cm			
T	k	k_e	k_g
4	0.0126	0.00353	[illegible]
6	0.0228	0.00530	0.0175
8	0.0321	0.00707	0.0251
10	0.0418	0.00884	0.0330
15	0.0658	0.0133	0.0525
20	0.0882	0.0177	0.0705
25	0.108‡	0.0216‡	0.0865
30	0.126‡	0.0257‡	0.100
40	0.154‡	0.0339‡	0.120
50	0.174‡	0.0417‡	0.132
60	0.189‡	0.0491‡	0.140
70	0.201*‡	0.0562‡	0.145
80	0.210*‡	0.0630‡	0.147
90	0.217*‡	0.0694‡	0.148
100	0.222*‡	0.0745‡	0.147
150	0.235*‡	0.0995‡	0.136
200	0.237*‡	0.127‡	0.110
250	0.237*‡	0.131‡	0.106
273	0.237*	0.138	0.0990
300	0.240*	0.147	0.0930
350	0.250*	0.166	0.0838
400	0.261*	0.185	0.0765
500	0.289*	0.222	0.0664
600	0.322*	0.265	0.0571
700	0.360*	0.309	0.0508
800	0.394*	0.343	0.0507
900	0.429*	0.385	0.0436
1000	0.461*	0.423	0.0382
1100	0.495*	0.460	0.0354
1200	0.528*	0.495	0.0330

† Uncertainties of the total thermal conductivity, k, are as follows:
50.00 Cu - 50.00 Ni: ± 15% below 20 K, ± 20% between 20 and 100 K, ± 10% between 100 and 200 K, and ± 5% above 200 K.
45.00 Cu - 55.00 Ni: ± 15% below 20 K, ± 20% between 20 and 150 K, and ± 10% above 150 K.
40.00 Cu - 60.00 Ni: ± 15% below 20 K, ± 20% between 20 and 200 K, and ± 10% above 200 K.
35.00 Cu - 65.00 Ni: ± 10% below 20 K, ± 20% between 20 and 250 K, and ± 10% above 250 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 11. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 30.00% (28.37 At.%) Ni: 70.00% (71.63 At.%)				Cu: 25.00% (23.55 At.%) Ni: 75.00% (76.45 At.%)				Cu: 20.00% (18.76 At.%) Ni: 80.00% (81.24 At.%)				Cu: 15.00% (14.02 At.%) Ni: 85.00% (85.98 At.%)			
ρ_0 = 23.70 μΩ cm				ρ_0 = 19.80 μΩ cm				ρ_0 = 16.00 μΩ cm				ρ_0 = 11.90 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0144*‡	0.00412	0.0103‡	4	0.0148*‡	0.00494	0.00985‡	4	0.0153*‡	0.00611	0.0092‡	4	0.0162‡	0.00622	0.00998‡
6	0.0237*‡	0.00619	0.0175‡	6	0.0238*‡	0.00740	0.0164‡	6	0.0244*‡	0.00916	0.0152‡	6	0.0258‡	0.0123	0.0135‡
8	0.0334*‡	0.00825	0.0251‡	8	0.0330*‡	0.00937	0.0236‡	8	0.0339*‡	0.0122	0.0217‡	8	0.0359‡	0.0164	0.0195‡
10	0.0433*‡	0.0103	0.0330‡	10	0.0433*‡	0.0123	0.0310‡	10	0.0438*‡	0.0153	0.0285‡	10	0.0465‡	0.0205	0.0260‡
15	0.0670*‡	0.0155	0.0515‡	15	0.0675*‡	0.0185	0.0490‡	15	0.0689*‡	0.0229	0.0460‡	15	0.0736‡	0.0306	0.0430‡
20	0.0896*‡	0.0206	0.0690‡	20	0.0917*‡	0.0247	0.0670‡	20	0.0955*‡	0.0305	0.0650‡	20	0.103‡	0.0411	0.0619‡
25	0.110*‡	0.0264‡	0.0845‡	25	0.114*‡	0.0303‡	0.0835‡	25	0.120*‡	0.0375‡	0.0825‡	25	0.130‡	0.0502‡	0.0800‡
30	0.129*‡	0.0303‡	0.0990‡	30	0.135*‡	0.0382‡	0.0965‡	30	0.144*‡	0.0440‡	0.0990‡	30	0.157‡	0.0587‡	0.0979‡
40	0.159*‡	0.0400‡	0.119‡	40	0.169*‡	0.0477‡	0.121‡	40	0.182*‡	0.0590‡	0.123‡	40	0.203‡	0.0783‡	0.125‡
50	0.180*‡	0.0492‡	0.131‡	50	0.195*‡	0.0586‡	0.136‡	50	0.212*‡	0.0725‡	0.139‡	50	0.239‡	0.0959‡	0.143‡
60	0.198*‡	0.0580‡	0.140‡	60	0.214*‡	0.0691‡	0.145‡	60	0.236*‡	0.0855‡	0.150‡	60	0.268*‡	0.113‡	0.155‡
70	0.212*‡	0.0665‡	0.146‡	70	0.230*‡	0.0792‡	0.151‡	70	0.255*‡	0.0977‡	0.157‡	70	0.292*‡	0.128‡	0.164‡
80	0.223*‡	0.0744‡	0.149‡	80	0.242*‡	0.0884‡	0.154‡	80	0.270‡	0.109‡	0.161‡	80	0.312‡	0.142‡	0.170‡
90	0.232*‡	0.0818‡	0.150‡	90	0.252*‡	0.0972‡	0.155‡	90	0.284*‡	0.120‡	0.164‡	90	0.328*‡	0.156‡	0.172‡
100	0.237*‡	0.0877‡	0.149‡	100	0.258*‡	0.104‡	0.154‡	100	0.293*‡	0.129‡	0.164‡	100	0.340*‡	0.167‡	0.173‡
150	0.253*‡	0.116‡	0.137‡	150	0.281*‡	0.138‡	0.143‡	150	0.320*‡	0.169‡	0.151‡	150	0.373*‡	0.214‡	0.159‡
200	0.256*‡	0.134‡	0.122‡	200	0.287*‡	0.161‡	0.126‡	200	0.330*‡	0.198‡	0.132‡	200	0.387*‡	0.247‡	0.140‡
250	0.257*‡	0.150‡	0.107‡	250	0.286*‡	0.176‡	0.110‡	250	0.332*‡	0.217‡	0.115‡	250	0.389*‡	0.267‡	0.122‡
273	0.257*‡	0.156‡	0.101‡	273	0.285*‡	0.181‡	0.104‡	273	0.331‡	0.223‡	0.108‡	273	0.388‡	0.273‡	0.114‡
300	0.257‡	0.162‡	0.0949‡	300	0.285‡	0.187‡	0.0977‡	300	0.330‡	0.228‡	0.102‡	300	0.388‡	0.280‡	0.107‡
350	0.261	0.175	0.0866‡	350	0.283‡	0.195‡	0.0880‡	350	0.325‡	0.234‡	0.0913‡	350	0.381‡	0.286‡	0.0950‡
400	0.272	0.194	0.0780‡	400	0.286*	0.206	0.0800‡	400	0.320‡	0.237‡	0.0829‡	400	0.373*‡	0.287‡	0.0860‡
500	0.296	0.232	0.0644‡	500	0.313*	0.245	0.0679‡	500	0.333	0.263	0.0701‡	500	0.369*	0.298	0.0720‡
600	0.331	0.273	0.0579‡	600	0.347*	0.288	0.0591‡	600	0.367	0.306	0.0608‡	600	0.397*	0.334	0.0630‡
700	0.369	0.318	0.0514‡	700	0.388*	0.335	0.0524‡	700	0.411	0.357	0.0537‡	700	0.445*	0.389	0.0556‡
800	0.404*	0.357	0.0463‡	800	0.422*	0.375	0.0471‡	800	0.445	0.397	0.0481‡	800	0.479*	0.429	0.0495‡
900	0.436*	0.394	0.0421‡	900	0.456*	0.413	0.0427‡	900	0.478	0.435	0.0435‡	900	0.510*	0.465	0.0448‡
1000	0.472*	0.433	0.0386‡	1000	0.489*	0.450	0.0391‡	1000	0.511*	0.471	0.0399‡	1000	0.539*	0.498	0.0406‡
1100	0.506*	0.470	0.0357‡	1100	0.521*	0.485	0.0361‡	1100	0.542*	0.505	0.0367‡	1100	0.567*	0.530	0.0376‡
1200	0.538*	0.505	0.0331‡	1200	0.552*	0.518	0.0335‡	1200	0.572*	0.538	0.0341‡	1200	0.594*	0.560	0.0345‡

† Uncertainties of the total thermal conductivity, k, are as follows:
30.00 Cu - 70.00 Ni: ± 15% below 20 K, ± 20% between 20 and 300 K, and ± 10% above 300 K.
25.00 Cu - 75.00 Ni: ± 15% below 20 K, ± 20% between 20 and 350 K, and ± 15% above 350 K.
20.00 Cu - 80.00 Ni: ± 15% below 20 K, ± 20% between 20 and 400 K, and ± 15% above 400 K.
15.00 Cu - 85.00 Ni: ± 15% below 20 K, ± 20% between 20 and 400 K, and ± 15% above 400 K.

‡ Provisional value.

§ Typical value.

* [illegible] where no experimental thermal conductivity data are available.

TABLE 11. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 10.00% (9.31 At.%) Ni: 90.00% (90.69 At.%)				Cu: 5.00% (4.64 At.%) Ni: 95.00% (95.36 At.%)				Cu: 3.00% (2.78 At.%) Ni: 97.00% (97.22 At.%)				Cu: 1.00% (0.92 At.%) Ni: 99.00% (99.08 At.%)			
ρ_0 = [illegible] μΩ cm				ρ_0 = 4.100 μΩ cm				ρ_0 = 2.400 μΩ cm				ρ_0 = 0.900 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	[illegible]	0.0122	0.00660‡	4	0.0279‡	0.0238	0.00410‡	4	0.0481*‡	0.0407	0.00740‡	4	0.123‡	0.109	0.0140‡
6	[illegible]	0.0183	0.0116‡	6	0.0438‡	0.0358	0.00800‡	6	0.0741*‡	0.0611	0.0130‡	6	0.186‡	0.163	0.0233‡
8	0.0415‡	0.0244	0.0171‡	8	0.0604‡	0.0477	0.0127‡	8	0.101*‡	0.0814	0.0192‡	8	0.250‡	0.217	0.0330‡
10	[illegible]	0.0305	[illegible]	10	0.0778‡	0.0596	0.0182‡	10	0.128*‡	0.102	0.0260‡	10	0.314‡	0.271	0.0433‡
15	0.0851‡	0.0458	0.0393‡	15	0.123‡	0.0894	0.0337‡	15	0.198*‡	0.153	0.0445‡	15	0.477‡	0.407	0.0695‡
20	0.118‡	0.0611‡	0.0570‡	20	0.171‡	0.119	0.0515‡	20	0.269*‡	0.204	0.0650‡	20	0.639‡	0.543	0.0960‡
25	[illegible]	[illegible]	[illegible]	25	0.217‡	0.146‡	0.0705‡	25	0.339*‡	0.242‡	0.0970‡	25	0.771‡	0.649‡	0.122‡
30	[illegible]	[illegible]	[illegible]	30	0.264‡	0.173‡	0.0910‡	30	0.397*‡	0.287‡	0.110‡	30	0.890‡	0.742‡	0.148‡
40	[illegible]	0.117‡	0.128‡	40	0.354‡	0.224‡	0.130‡	40	0.516*‡	0.363‡	0.153‡	40	1.07‡	0.875‡	0.195‡
50	[illegible]	0.143‡	0.150‡	50	0.433‡	0.268‡	0.165‡	50	0.613*‡	0.424‡	0.189‡	50	1.19‡	0.952‡	0.235‡
60	[illegible]	0.165‡	0.166‡	60	0.497‡	0.306‡	0.191‡	60	0.688*‡	0.473‡	0.215‡	60	1.21‡	0.945‡	0.265‡
70	[illegible]	0.187‡	0.178‡	70	0.543‡	0.337‡	0.206‡	70	0.734*‡	0.504‡	0.230‡	70	1.21‡	0.924‡	0.283‡
80	[illegible]	0.204‡	0.186‡	80	0.578‡	0.362‡	0.216‡	80	0.765*‡	0.524‡	0.241‡	80	1.19‡	0.899‡	0.293‡
90	0.411*‡	0.221‡	0.190‡	90	0.599*‡	0.378‡	0.221‡	90	0.784*‡	0.537‡	0.247‡	90	1.16‡	0.866‡	0.295‡
100	[illegible]	0.234‡	0.192‡	100	0.614*‡	0.391‡	0.223‡	100	0.786*‡	0.536‡	0.250‡	100	1.11‡	0.823‡	0.290‡
150	0.465*‡	0.287‡	0.178‡	150	0.642*‡	0.436‡	0.206‡	150	0.779*‡	0.554‡	0.225‡	150	0.993*‡	0.741‡	0.252‡
200	[illegible]	[illegible]	[illegible]	200	0.637*‡	0.463‡	0.174‡	200	0.743*‡	0.557‡	0.186‡	200	0.900*‡	0.698‡	0.202‡
250	0.473*‡	0.342‡	0.131‡	250	0.623*‡	0.476‡	0.147‡	250	0.717*‡	0.561‡	0.156‡	250	0.838*‡	0.670‡	0.168‡
273	[illegible]	[illegible]	0.123‡	273	0.616*‡	0.479‡	0.137‡	273	0.704*‡	0.559‡	0.145‡	273	0.819*‡	0.663‡	0.155‡
300	0.471‡	0.356‡	0.115‡	300	0.608‡	0.481‡	0.127‡	300	0.692*‡	0.558‡	0.134‡	300	0.801*‡	0.658‡	0.143‡
350	[illegible]	[illegible]	0.103‡	350	0.591‡	0.479‡	0.112‡	350	0.665*‡	0.547‡	0.118‡	350	0.764*‡	0.640‡	0.124‡
400	[illegible]	[illegible]	0.0923‡	400	0.566*‡	0.466‡	0.100‡	400	0.635*‡	0.530‡	0.105‡	400	0.724*‡	0.615‡	0.110‡
500	[illegible]	[illegible]	0.0770‡	500	0.523‡	0.441‡	0.0826‡	500	0.581*‡	0.495‡	0.0855‡	500	0.655*‡	0.566‡	0.0890‡
600	[illegible]	0.371	[illegible]	600	0.494	0.424	0.0702‡	600	0.527*‡	0.455‡	0.0723‡	600	0.598*‡	0.523‡	0.0747‡
700	[illegible]	[illegible]	[illegible]	700	0.547*	0.486	0.0610‡	700	0.581*	0.518	0.0626‡	700	0.619*	0.553	0.0643‡
800	[illegible]	[illegible]	0.0514‡	800	0.579*	0.525	0.0539‡	800	0.611*	0.556	0.0551‡	800	0.643*	0.587	0.0565‡
900	[illegible]	[illegible]	0.0463‡	900	0.607*	0.559	0.0483‡	900	0.636*	0.586	0.0493‡	900	0.669*	0.618	0.0503‡
1000	[illegible]	[illegible]	0.0421‡	1000	0.635*	0.591	0.0437‡	1000	0.662*	0.618	0.0445‡	1000	0.692*	0.646	0.0454‡
1100	[illegible]	[illegible]	0.0386‡	1100	0.661*	0.621	0.0400‡	1100	0.687*	0.646	0.0406‡	1100	0.715*	0.673	0.0413‡
1200	[illegible]	[illegible]	0.0357‡	1200	0.686*	0.649	0.0368‡	1200	0.710*	0.672	0.0373‡	1200	0.736*	0.698	0.0379‡

† Uncertainties of the total thermal conductivity, k, are as follows:
10.00 Cu - 90.00 Ni: ±20% below 20 K, ±25% between 20 and 500 K, and ±15% above 500 K.
5.00 Cu - 95.00 Ni: ±20% below 20 K, ±25% between 20 and 500 K, and ±15% above 500 K.
3.00 Cu - 97.00 Ni: ±20% below 20 K, ±25% between 20 and 600 K, and ±15% above 600 K.
1.00 Cu - 99.00 Ni: ±20% below 20 K, ±25% between 20 and 600 K, and ±15% above 600 K.

* Provisional value.

‡ Typical value.

[illegible] thermal conductivity data are available.

TABLE 11. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

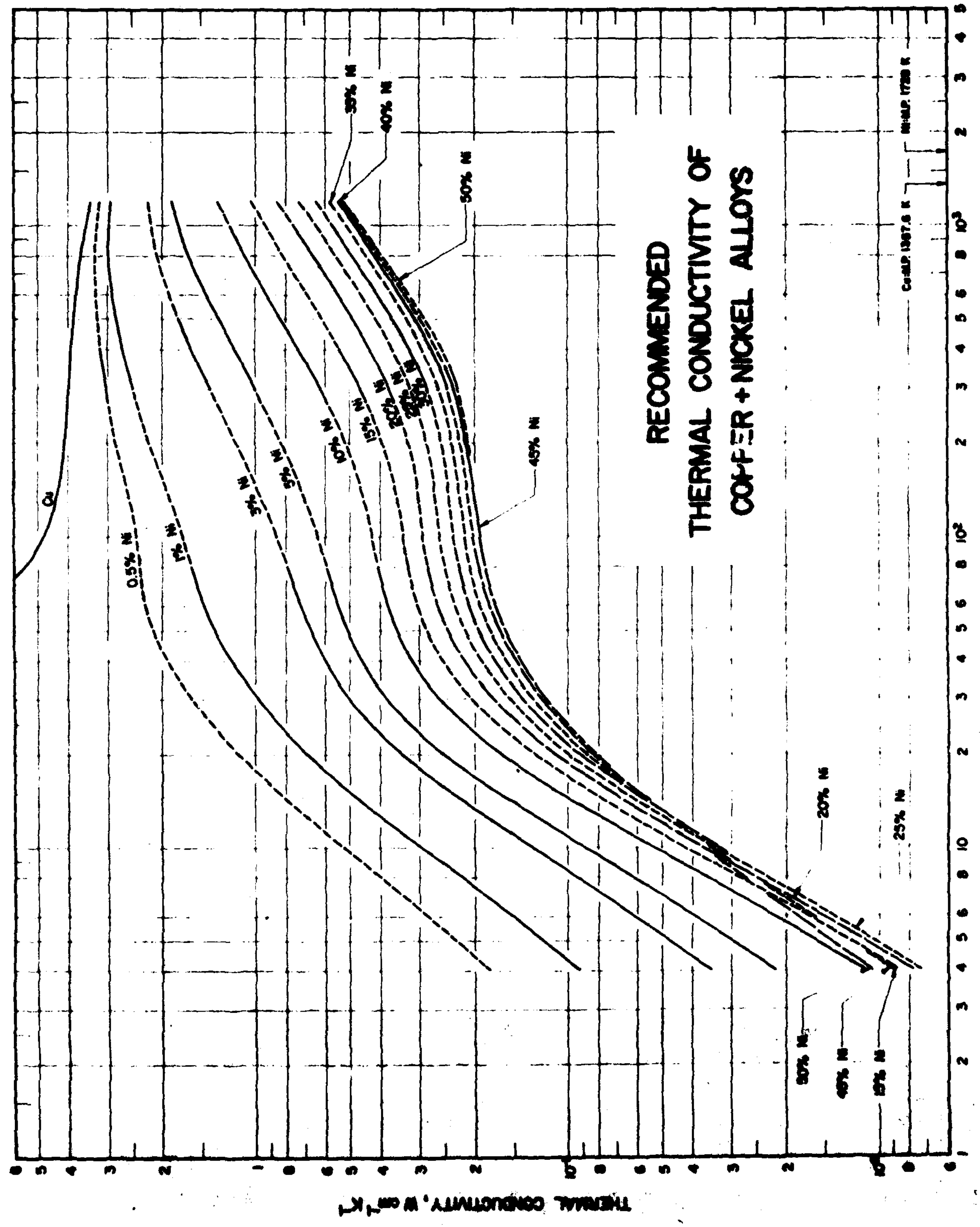
Cu: 0.50% (0.46 At.%) Ni: 99.50% (99.54 At.%)						
ρ_0 = 0.300 μΩ cm						
T	k	k_e	k_g			
4	0.212‡	0.195	0.0170‡			
6	0.321‡	0.293	0.0275‡			
8	0.430‡	0.391	0.0390‡			
10	0.540‡	0.489	0.0510‡			
15	0.818‡	0.738	0.0800‡			
20	1.09‡	0.977	0.110‡			
25	1.31‡	1.17‡	0.140‡			
30	1.46‡	1.29‡	0.170‡			
40	1.6[illegible]‡	1.40‡	0.220‡			
50	[illegible]	1.39‡	0.260‡			
60	[illegible]	1.35‡	0.290‡			
70	[illegible]	1.29‡	0.300‡			
80	1.45‡	1.13‡	0.310‡			
90	1.3[illegible]‡	1.04‡	0.320‡			
100	[illegible]	0.960‡	0.310‡			
150	1.[illegible]‡	0.796‡	0.263‡			
200	0.9[illegible]‡	0.745‡	0.200‡			
250	0.[illegible]‡	0.717‡	0.171‡			
273	0.[illegible]‡	0.701‡	0.156‡			
300	0.[illegible]‡	0.693‡	0.148‡			
350	0.7[illegible]‡	0.667‡	0.126‡			
400	0.7[illegible]‡	0.641‡	0.111‡			
500	0.67[illegible]‡	0.589‡	0.0890‡			
600	0.61[illegible]‡	0.543‡	0.0755‡			
700	0.6[illegible]*	0.554	0.0646‡			
800	0.65[illegible]*	0.596	0.0580‡			
900	0.67[illegible]*	0.627	0.0500‡			
1000	0.70[illegible]*	0.654	0.0456‡			
1100	0.72[illegible]*	0.682	0.0418‡			
1200	0.74[illegible]*	0.700	0.0381‡			

† Uncertainties of the total thermal conductivity, k, are as follows:
0.50 Cu – 99.50 Ni: ±20% below 20 K, ±25% between 20 and 600 K, and ±15% above 600 K.

‡ Provisional values.

§ Typical values.

* In temperature range where no experimental thermal conductivity data are available.


RECOMMENDED
THERMAL CONDUCTIVITY OF
COPPER + NICKEL ALLOYS
Cu
0.5% Ni
1% Ni
3% Ni
5% Ni
10% Ni
15% Ni
20% Ni
25% Ni
30% Ni
35% Ni
40% Ni
45% Ni
50% Ni
Cu M.P. 1357.6 K
Ni M.P. 1728 K
TEMPERATURE, K
THERMAL CONDUCTIVITY, W cm^{-1} K^{-1}
TPRC
FIGURE 17

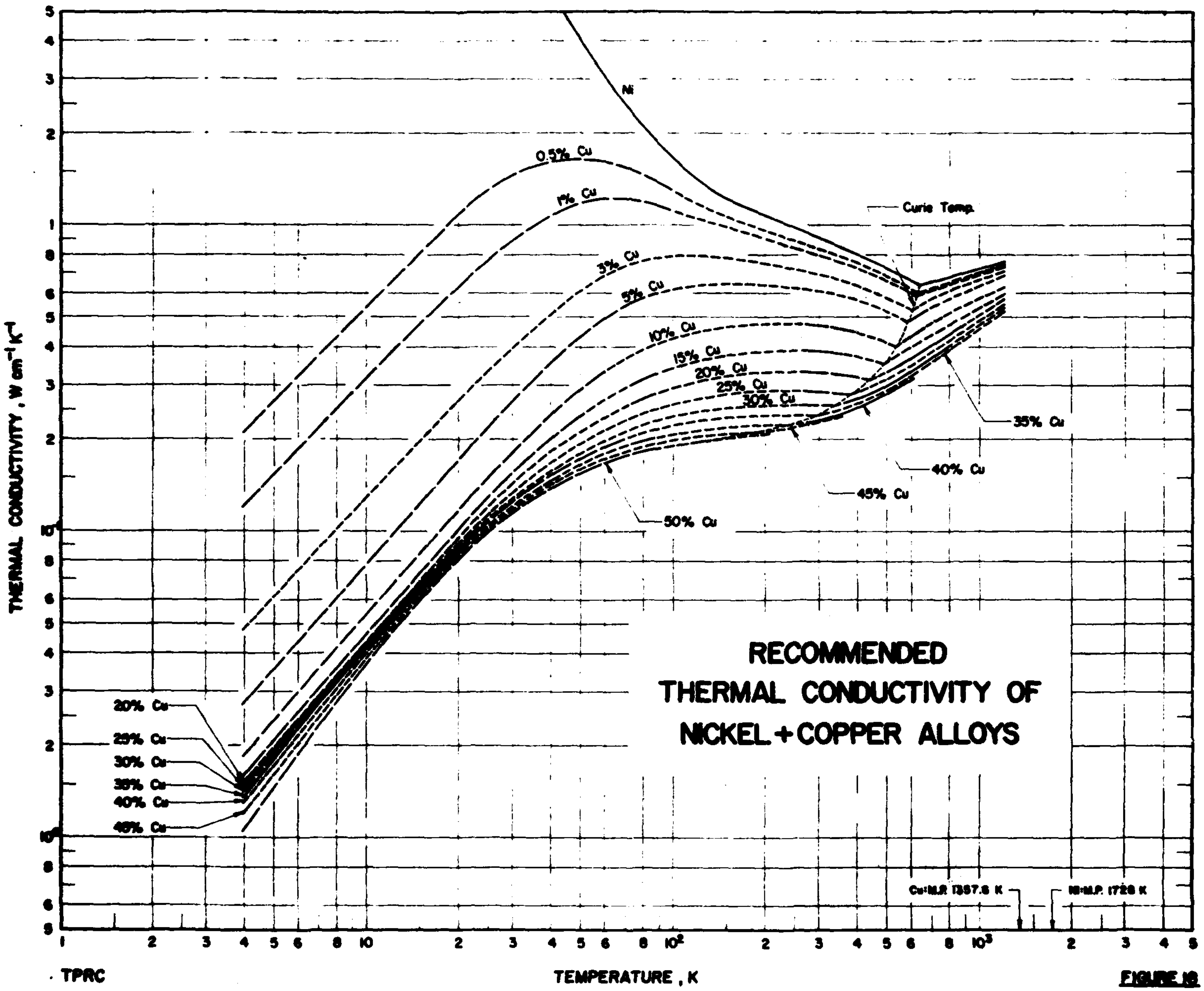
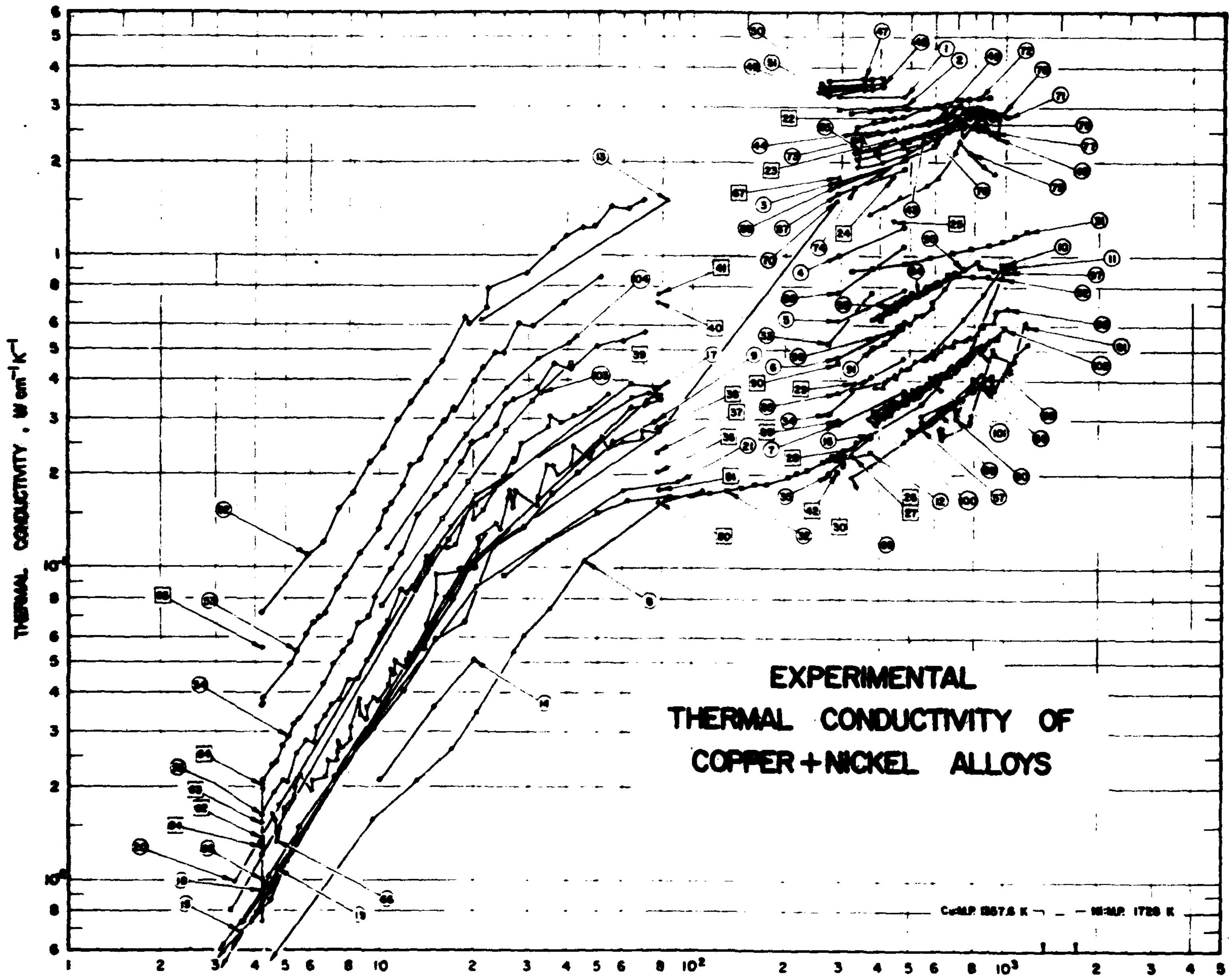
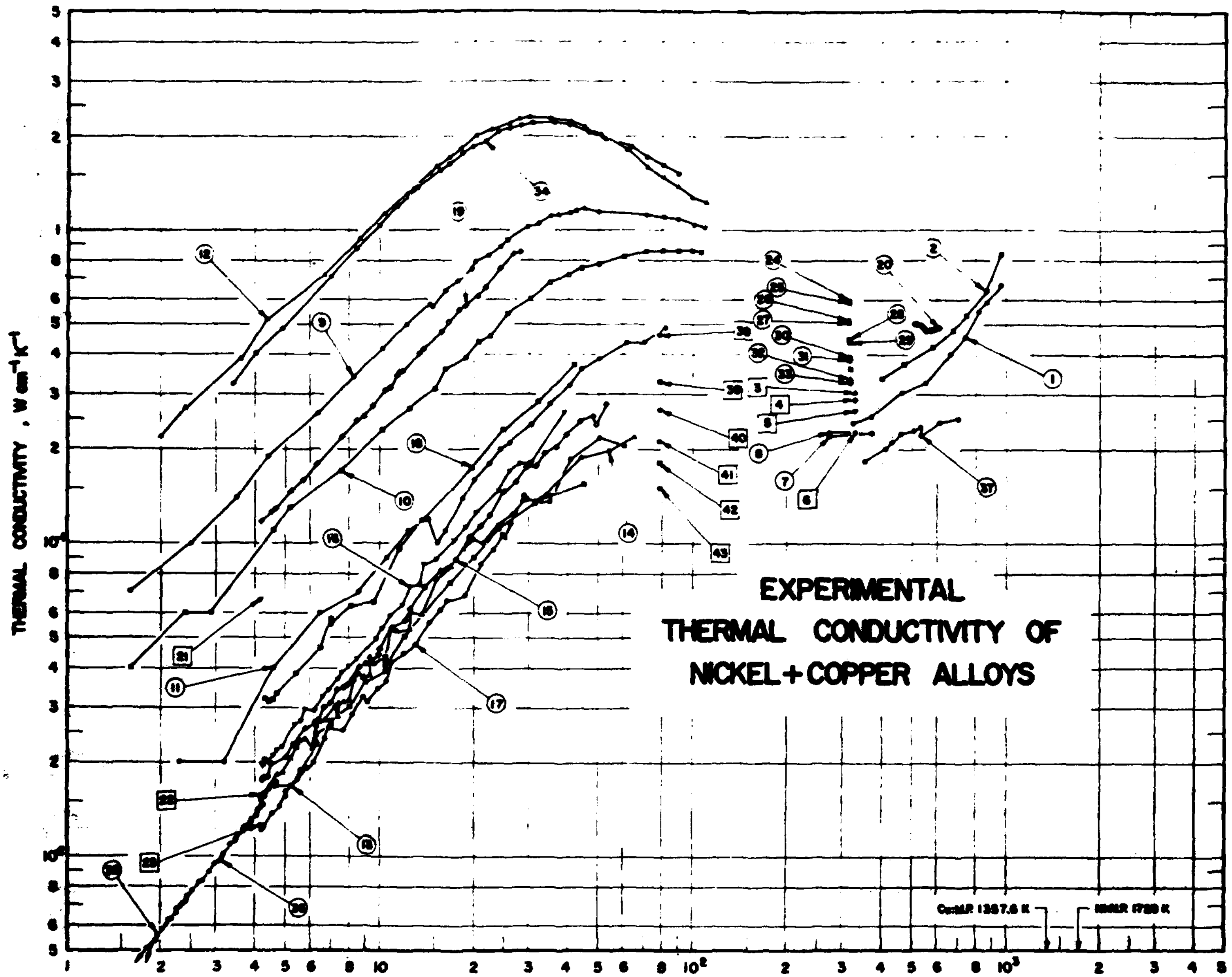

RECOMMENDED
THERMAL CONDUCTIVITY OF
NICKEL + COPPER ALLOYS
THERMAL CONDUCTIVITY, W cm⁻¹ K⁻¹
TEMPERATURE, K
Ni
0.5% Cu
1% Cu
3% Cu
5% Cu
10% Cu
15% Cu
20% Cu
25% Cu
30% Cu
35% Cu
40% Cu
45% Cu
50% Cu
Curie Temp.
Cu:M.P. 1357.6 K
Ni:M.P. 1728 K
TPRC

FIGURE 16



TPRC

FIGURE 19



TPRC

FIGURE 20

TABLE 12. THERMAL CONDUCTIVITY OF COPPER + NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
1	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 107	99.73	0.28	0.03 Mg and 0.01 Fe; specimen 0.75 in. in diameter and 8 in. long; supplied by American Brass Co.; cold-rolled, annealed, and cold-drawn; annealed at 800 C for 2 hr; electrical conductivity 45.70 and 29.11 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 20 and 200 C, respectively.
2	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 108	99.47	0.54	0.04 Mg and 0.02 Fe; similar to the above specimen except electrical conductivity 39.94 and 26.86 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 20 and 200 C, respectively.
3	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 109	97.94	1.97	0.04 Mg and 0.02 Fe; similar to the above specimen except annealed at 800 C for 4 hr; electrical conductivity 22.71 and 17.58 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 20 and 200 C, respectively.
4	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 110	94.92	5.09	0.03 Mg and 0.01 Fe; similar to the above specimen except electrical conductivity 12.39 and 10.64 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 20 and 200 C, respectively.
5	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 111	89.90	10.07	0.03 Mg, 0.024 C, and 0.02 Fe; similar to the above specimen except electrical conductivity 7.07 and 6.46 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 20 and 200 C, respectively.
6	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 125	84.85	15.07	0.06 Fe, 0.08 Mn, and 0.01 Mg; similar to the above specimen except electrical conductivity 5.094 and 4.795 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 20 and 200 C, respectively.
7	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 124	69.54	30.23	0.13 Mn, 0.05 Fe, and 0.05 Mg; similar to the above specimen except electrical conductivity 2.754 and 2.730 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 20 and 200 C, respectively.
8	68	Zavaritskii, N.V. and Zeldovich, A.G.	1956	L	2.3-106	Russian cupro nickel NM-81; 7	81.0	19.0	Specimen in strip form cut from a 6 x 5 mm tube; measured in helium.
9	68	Zavaritskii, N.V. and Zeldovich, A.G.	1956	L	2.5-76	Russian cupro nickel NM-81; 6	81.0	19.0	The above specimen; annealed at 800 C; measured in helium.
10	77	Sager, G.F.	1930	P	321-964		≈79.8	20.0	0.2 Mn and trace Mg; ~0.25 cm in diameter and ~3.5 cm long; chill cast, hot rolled and cold drawn; annealed at 700 C for 12 hr; electrical conductivity 3.54, 3.46, 3.33, 3.21, 3.12, and 3.02 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 48, 150, 315, 462, 575, and 711 C, respectively.
11	77	Sager, G.F.	1930	P	335-991		≈59.8	40.0	Similar to the above specimen except electrical conductivity 1.99, 1.99, 1.96, and 1.92 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 62, 266, 510, and 717 C, respectively.
12	127	Barratt, T.	1914	F	273-373	Eureka	60.0	40.0	0.0995 cm diameter and 40.0 cm long; electrical resistivity 45.90 and 45.87 $\mu\Omega$ cm at 0 and 100 C, respectively.
13	128	Grüneisen, E. and Goens, E.	1927	L	21,83	Cu 11	99.0	1.0	7 cm long and 0.1 to 0.3 cm wide; drawn; electrical resistivity 2.97, 1.60, and 1.295 $\mu\Omega$ cm at 0, -190, and -252 C, respectively.
14	71	Wilkinson, K.R. and Wilks, J.	1949	L	10-20	Cupro-nickel	70	30	4.1 mm in O.D., 2.5 mm in I.D., and 21 mm long; supplied by Yorkshire Copper Works Ltd.; cold-worked.
15	60	Hulm, J.K.	1951	L	1.9-22		80	20	Average grain size 0.011 mm.
16	129	Jaeger, W. and Diesselhorst, H.	1900	E	291,375	Constantan	60	40	1.996 cm diameter and 27 cm long; density 8.92 g cm^{-3} at 18 C; electrical conductivity 2.04 and 2.037 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 18 and 100 C, respectively.

TABLE 12. THERMAL CONDUCTIVITY OF COPPER - NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
17	130, 176	Zimmerman, J.E.	1951	L	3.3-78	CN 1	90	10	Cylindrical specimen 0.125 in. in diameter; machined from a forged bar; electrical resistivity 12.50, 12.72, and 14.68 $\mu\Omega$ cm at 19.7, 78.9, and 296 K, respectively.
18	130, 176	Zimmerman, J.E.	1951	L	3.0-77	CN 2	90	10	Cylindrical specimen 0.125 in. in diameter; cold-worked by rolling from 0.25 in. thick to 0.14 in. before being machined to size; electrical resistivity 12.65 and 14.69 $\mu\Omega$ cm at 76.2 and 296 K, respectively.
19	130, 176	Zimmerman, J.E.	1951	L	3.6-79	CN 3	90	10	Cylindrical specimen 0.125 in. in diameter; severely cold-worked; rolled from 0.5 in.^{2} cross section to 0.22 x 0.24 in. before machining; electrical resistivity 12.63 and 14.65 $\mu\Omega$ cm at 78.7 and 298 K, respectively.
20	130, 176	Zimmerman, J.E.	1951	L	3.4-79	CN 4	90	10	Single crystal; cylindrical specimen 0.125 in. in diameter; electrical resistivity 13.0, 13.10, and 15.04 $\mu\Omega$ cm at 20.5, 79.3, and 296 K, respectively.
21	70	Berman, R.	1951	L	3.0-91	Constantan	60	40	317 36 gauge wires bound and soldered together at ends; electrical resistivity 44.3, 45.3, and 52.7 $\mu\Omega$ cm at 20, 90, and 290 K, respectively.
22	47	Hanson, D. and Rodgers, C.E.	1932	L	438.2		Bal.	0.78	Prepared from high grade electrolytic Cu with traces of impurities; 6.5 in. long and 0.5 in. in diameter; annealed at 900 C.
23	47	Hanson, D. and Rodgers, C.E.	1932	L	438.2		Bal.	1.57	Similar to the above specimen.
24	47	Hanson, D. and Rodgers, C.E.	1932	L	438.2		Bal.	2.76	Similar to the above specimen.
25	47	Hanson, D. and Rodgers, C.E.	1932	L	438.2		Bal.	4.9	Similar to the above specimen.
26	45	Smith, A.W.	1925	L	330.2		50	50	~5 cm long with cross section 0.3 cm^2; made from Cu (< 0.03 of total impurity) supplied by Baker by fusing with Ni (99.75 to 99.85 pure including cobalt) supplied by International Nickel Co. of America; electrical conductivity 1.98 x 10^4 Ω^{-1} cm^{-1} at 25 C.
27	45	Smith, A.W.	1925	L	330.2		60	40	Similar to the above specimen except electrical conductivity 2.04 x 10^4 Ω^{-1} cm^{-1} at 25 C.
28	45	Smith, A.W.	1925	L	330.2		70	30	Similar to the above specimen except electrical conductivity 2.48 x 10^4 Ω^{-1} cm^{-1} at 25 C.
29	45	Smith, A.W.	1925	L	330.2		90	10	Similar to the above specimen except electrical conductivity 3.49 x 10^4 Ω^{-1} cm^{-1} at 25 C.
30	131	Ellis, W.C., Morgan, F.L. and Sager, F.G.	1928	P	305.2	Advance	55	45	0.25 cm diameter and 35 cm long; density 8.78 g cm^{-3}; electrical conductivity 2.023 x 10^4 Ω^{-1} cm^{-1} at 32 C; thermal conductivity value calculated from measured thermal diffusivity, specific heat capacity, and density.
31	132	Silverman, L.	1953	C	323-1174	Lohm	93.4	6.05	0.01 Mn and 0.01 Si; annealed at 900 C; advance used as comparative material.
32	133	Powers, R.W., Ziegler, J.B. and Johnston, H.L.	1951	L	26-295	Constantan	55	45	No details given.

TABLE 12. THERMAL CONDUCTIVITY OF COPPER + NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
33	63	Sedström, E.	1919	T	273, 373		89.94	10.06	Calculated composition; rolled and drawn to 1 mm thick; heated 0.5 hr close to melting point; electrical conductivity 6.2 and 6.1 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
34	63	Sedström, E.	1919	T	273, 373		79.90	20.10	Similar to the above specimen except electrical conductivity 3.5 and 3.3 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
35	63	Sedström, E.	1919	T	273, 373		60.02	39.98	Similar to the above specimen except electrical conductivity 2.0 and 2.0 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
36	134	Aoyama, S. and Ito, T.	1940	L	78.2	8		29.89	0.03 Mn, 0.03 Fe, and traces of other impurities; prepared from electrolytic Ni (containing 0.53 Co, 0.05 Fe, and 0.02 Al) and electrolytic Cu (containing 0.015 Sb, 0.01 Fe, 0.007 S, and trace of P) by fusing; 4.00 mm in diameter and 60.0 mm long; electrical resistivity 40.3 $\mu\Omega$ cm at -195 C.
37	134	Aoyama, S. and Ito, T.	1940	L	78.2	9		19.83	0.04 Mn, 0.02 Fe, and traces of other impurities; the same original materials and dimensions as the above specimen; electrical resistivity 27.1 $\mu\Omega$ cm at -195 C.
38	134	Aoyama, S. and Ito, T.	1940	L	78.2	10		13.84	0.11 Fe and trace Mn; the same original materials and dimensions as the above specimen; electrical resistivity 17.6 $\mu\Omega$ cm at -195 C.
39	134	Aoyama, S. and Ito, T.	1940	L	78.2	11		9.47	0.14 Fe, traces of Mn and other impurities; the same original materials and dimensions as the above specimen; electrical resistivity 11.9 $\mu\Omega$ cm at -195 C.
40	134	Aoyama, S. and Ito, T.	1940	L	78.2	12		3.67	0.09 Fe and traces of other impurities; the same original materials and dimensions as the above specimen; electrical resistivity 3.43 $\mu\Omega$ cm at -195 C.
41	134	Aoyama, S. and Ito, T.	1940	L	78.2	13	98.94	1.03	0.03 Fe and traces of other impurities; the same original materials and dimensions as the above specimen; electrical resistivity 1.039 $\mu\Omega$ cm at -195 C.
42	135	Grüneisen, E.	1900	L	291.2		54	46	Density 8.89 g cm^{-3}; electrical conductivity 1.98 x $10^5\ \Omega^{-1}\ cm^{-1}$ at 18 C.
43	144	Mikryukov, V.E.	1957		336-825		99.05	0.70	0.1 Be and 0.15 Co; electrical conductivity 25.8, 23.1, 20.4, 18.25, 16.5, 15.67, and 14.33 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 63.0, 114.6, 195, 273, 375.8, 438.5, and 551.3 C, respectively.
44	138	Mikryukov, V.E.	1957		333-900		Bal.	0.90	0.10 Be and 0.10 Zr; electrical resistivity 3.34, 3.85, 4.33, 5.21, 5.78, 6.33, 7.05, and 8.14 $\mu\Omega$ cm at 59.4, 118.6, 171.5, 291.6, 365.6, 457, 534.5, and 626.5 C, respectively.
45	138	Mikryukov, V.E.	1957		336-947		Bal.	0.80	0.20 Ti; electrical resistivity 4.25, 4.88, 5.56, 6.01, 6.46, 6.57, 7.18, 7.28, 7.66, 8.93, and 9.76 $\mu\Omega$ cm at 62.8, 130.9, 217.5, 290.6, 462.5, 440.3, 560.3, 538.3, 674.3, 618.0, and 673.6 C, respectively.
46	138	Mikryukov, V.E.	1957		345-923		Bal.	0.55	0.17 Zr; electrical resistivity 3.45, 4.13, 4.43, 5.10, 5.32, 5.78, 6.20, 6.83, 7.20, and 8.07 $\mu\Omega$ cm at 71.8, 158.7, 201.0, 291.0, 331.0, 401.4, 473.6, 534.5, 575.0, and 649.5 C, respectively.
47	137	Chubb, W.F.	1938	L	273-403		Bal.	0.204	$\approx$0.079 O; specimen 50.6 cm long.
48	137	Chubb, W.F.	1938	L	273-403		Bal.	0.303	$\approx$0.079 O; specimen 50.6 cm long.
49	137	Chubb, W.F.	1938	L	273-403		Bal.	0.506	$\approx$0.079 O; specimen 50.6 cm long.

TABLE 12. THERMAL CONDUCTIVITY OF COPPER + NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
50	137	Chubb, W.F.	1938	L	273-403		Bal.	0.303	0.0042 Fe, 0.0014 Pb, trace Sn and Zn; specimen 50.6 cm long.
51	137	Chubb, W.F.	1938	L	273-403		Bal.	0.508	~0.022 O; specimen 50.6 cm long.
52	74	Erdmann, J.C. and Jahoda, J.A.	1968	L	4.2-70	Cu 98		2.29	Single crystal; 6.0-7.5 mm diameter and 12 cm long; prepared by electron beam float zoning; supplied by Materials Research Corp.; residual electrical resistivity 2.17 $\mu\Omega$ cm; measured in a vacuum of 10^{-6} mm Hg.
53	74	Erdmann, J.C. and Jahoda, J.A.	1968	L	4.2-51	Cu 96		4.05	Similar to the above specimen except residual electrical resistivity 4.95 $\mu\Omega$ cm.
54	74	Erdmann, J.C. and Jahoda, J.A.	1968	L	4.2-71	Cu 91		9.30	0.025 Al; polycrystalline; 5.0 mm in diameter and 10 cm long; vacuum cast ingot hammer forged, hot rolled to 18 mm diameter and rough turned, the rough swaged to 10 mm in diameter, then machined to size; annealed at 930 C for 24 hr in the argon furnace and allowed to cool slowly; residual electrical resistivity 11.22 $\mu\Omega$ cm; measured in a vacuum of 10^{-6} mm Hg.
55	74	Erdmann, J.C. and Jahoda, J.A.	1968	L	4.2-54	Cu 72		27.96	0.023 Al; similar to the above specimen except residual electrical resistivity 33.38 $\mu\Omega$ cm.
56	138	Kummer, D.L., Rosenthal, J.J. and Lum, D.W.	1965	C	498-849	Constantan, No. 103	~60	~40	Thermocouple grade; 1 in. diameter and 1 in. thick; Armco iron used as comparative material.
57	138	Kummer, D.L., et al.	1965	C	539-908	Constantan, No. 103	~60	~40	2.5 in. O.D., 0.75 in. I.D., and 3 in. long.
58	139	Carroll, J.M.	1964	C	492-850	Constantan; Specimen No. 1	~60	~40	Thermocouple grade; 1 in. in diameter and 1 in. long; Armco iron used as comparative material.
59*	139	Carroll, J.M.	1964	C	499-850	Constantan; Specimen No. 2	~60	~40	Similar to the above specimen.
60	139	Carroll, J.M.	1964	R	693-1044	Constantan; Specimen No. 1	~60	~40	Thermocouple grade; 0.25 in. I.D., 1 in. O.D., and 1 in. long.
61	139	Carroll, J.M.	1964	R	622-1175	Constantan; Specimen No. 3	~60	~40	Similar to the above specimen.
62	73	Erdmann, J.C. and Jahoda, J.A.	1964	L	4.2	Ko	Bal.	~40	Polycrystalline; wire specimen 1.35 to 1.45 mm in diameter and 125 mm long; obtained from International Nickel Co.; vacuum cast ingot hammer forged; hot rolled to 18.5 mm diameter, rough turned, cold rolled to 6 mm diameter and drawn to 1.5 mm diameter, cut; annealed at 1000 C for 24 hr, slowly cooled in the furnace over a period of 6 hr, electro-polished; electrical resistivity 42.3 $\mu\Omega$ cm at 4.2 K.
63	73	Erdmann, J.C. and Jahoda, J.A.	1964	L	4.2	666	Bal.	9.3	0.025 Al; polycrystalline; same dimensions, supplier, and fabrication method as the above specimen; electrical resistivity 10.94 $\mu\Omega$ cm at 4.2 K.
64	73	Erdmann, J.C. and Jahoda, J.A.	1964	L	4.2	664	Bal.	4.74	<0.1 each of Fe, Mg, and Mn, and 0.043 Al; polycrystalline; same dimensions, supplier, and fabrication method as the above specimen; electrical resistivity 7.04 $\mu\Omega$ cm at 4.2 K.
65	73	Erdmann, J.C. and Jahoda, J.A.	1964	L	4.2	868	Bal.	1.96	Polycrystalline; same dimensions, supplier, and fabrication method as the above specimen; electrical resistivity 2.17 $\mu\Omega$ cm at 4.2 K.

* Not shown in figure.

TABLE 12. THERMAL CONDUCTIVITY OF COPPER + NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
66	140	Erdmann, J.C. and Jahoda, J.A.	1968	L	4.6-78	Cu 72 Ni 28	72	28	Polycrystalline; 1.35 to 1.45 mm in diameter and 130 mm long; obtained from International Nickel Co., Inc.; vacuum cast ingot hammer forged, hot-rolled to 18.5 mm diameter, rough turned, cold-rolled to 6 mm diameter and drawn to 1.5 mm diameter, cut, annealed in argon atmosphere at 1000 C for 24 hr, slowly cooled in the furnace over a period of 6 hr, electropolished; grain size 50 to 200 μ.
67	83	Kierspe, W.	1967	L	293.2			1.85	Cylindrical specimen; electrical resistivity 2.2466, 2.2492, 2.2521, 2.2662, 2.2993, 2.3492, 2.4812, 2.5802, 2.7301, 2.8618, 3.0326, 3.1811, 3.3266, 3.4710, 3.6146, 3.7563, 3.8972, and 3.9674 μΩ cm at 4.2, 10, 20, 30, 40, 50, 70, 83, 103, 123, 143, 163, 183, 203, 223, 243, 263, and 273 K, respectively.
68	72, 141	Erdmann, J.C. and Jahoda, J.A.	1962	E	4.2	Constantan	60	40	Commercial alloy; about 1 to 3 mm in diameter and about 100 mm long; annealed; measured in different strain conditions.
69	132	Silverman, L.	1953	C	323-1173	Advance	54.79	44.04	1.20 Mn, 0.035 C, and 0.003 Si; cylindrical bar specimen; annealed at 900 C; lead used as comparative material; smoothed values reported.
70	142	Zlunitsyn, S. and Savel'ev, I.V.	1939	L	18-290	Cupronickel	77.44	20.48	1.99 Zn; 4.97 mm O.D., 4.16 mm I.D., and 67 mm long.
71	144, 145	Mikryukov, V.E.	1957	E	321-1002		99.03	0.60	0.27 Zr and 0.1 P; electrical conductivity 36.70, 32.15, 27.61, 24.70, 21.70, 19.34, 17.54, 15.80, 14.56, 13.36, 12.64, and 11.38 x 10^4 Ω^{-1} cm^{-1} at 47.3, 94.0, 155.5, 211.0, 283.5, 354.3, 432.1, 493.8, 560.5, 616.3, 655.1, and 729.0 C, respectively.
72	144, 145	Mikryukov, V.E.	1957	E	334-884		98.99	0.60	0.26 Zr and 0.15 Sn; electrical conductivity 32.00, 28.95, 24.82, 22.12, 20.71, 18.47, 17.43, 16.23, and 15.00 x 10^4 Ω^{-1} cm^{-1} at 61.0, 106.5, 193.0, 261.5, 331.3, 442.0, 482.0, 544.0, and 611.0 C, respectively.
73	136	Mikryukov, V.E.	1957	E	336-946		99.0	0.80	0.20 Ti; electrical conductivity 23.50, 20.50, 17.97, 16.65, 15.48, 15.20, 14.91, 13.72, 11.20, and 10.22 x 10^4 Ω^{-1} cm^{-1} at 62.6, 130.0, 217.5, 290.6, 362.5, 440.3, 536.3, 580.3, 618.0, and 673.6 C, respectively.
74	136	Mikryukov, V.E.	1957	E	329-774		98.35	0.40	0.25 P; electrical conductivity 19.96, 18.60, 17.35, 15.44, 16.22, and 13.40 x 10^4 Ω^{-1} cm^{-1} at 56.0, 118.8, 201.0, 316.0, 422.0, and 500.5 C, respectively.
75	136	Mikryukov, V.E.	1957	E	370-920		98.50	1.20	0.30 Si; electrical conductivity 15.02, 14.30, 13.67, 12.25, 11.80, 12.65, 13.13, 11.35, 9.11, and 8.06 x 10^4 Ω^{-1} cm^{-1} at 96.6, 135.6, 194.8, 279.0, 333.1, 413.0, 420.0, 493.3, 570.0, and 646.6 C, respectively.
76	136	Mikryukov, V.E.	1957	E	331-815		98.73	0.80	0.33 Zr and 0.14 Be; electrical conductivity 25.70, 23.10, 22.00, 19.85, 17.30, 15.60, 14.60, and 13.65 x 10^4 Ω^{-1} cm^{-1} at 58.0, 123.0, 126.0, 195.8, 290.3, 405.6, 483.0, and 542.0 C, respectively.
77	136	Mikryukov, V.E.	1957	E	333-910		98.53	1.0	0.33 Zr and 0.14 Be; electrical conductivity 24.65, 22.00, 19.25, 17.13, 16.20, 15.32, 12.75, and 11.35 x 10^4 Ω^{-1} cm^{-1} at 60.0, 117.0, 195.8, 282.0, 354.3, 442.0, 544.8, and 637.0 C, respectively.
78	136	Mikryukov, V.E.	1957	E	326-974		99.13	0.62	0.25 Zr; electrical conductivity 29.3, 24.7, 21.1, 18.4, 17.2, 16.8, 14.8, 12.9, and 11.7 x 10^4 Ω^{-1} cm^{-1} at 52.6, 131.5, 225.4, 335.3, 403.8, 435.9, 532.9, 636.7, and 701.1 C, respectively.

TABLE 12. THERMAL CONDUCTIVITY OF COPPER + NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
79	136	Mikryukov, V.E.	1957	E	333-855		49.3	0.28	0.24 Zr and 0.19 Be; electrical conductivity 26.10, 22.90, 19.50, 17.46, 15.30, 14.34, 13.40, and 12.12 x 10^4 Ω^{-1} cm^{-1} at 59.8, 119.5, 216.5, 302.6, 383.0, 455.1, 522.0, and 581.6 C, respectively.
80	134	Aoyama, S. and Ito, T.	1940	L	78.2	6	Bal.	49.45	0.26 Co, 0.06 Fe, 0.05 Mn, 0.01 Al, 0.008 Sb, 0.004 S, and trace Pb (calculated composition); electrical resistivity 54.9 $\mu\Omega$ cm.
81	134	Aoyama, S. and Ito, T.	1940	L	78.2	7	Bal.	39.6	0.21 Co, 0.07 Fe, 0.02 Mn, 0.009 Sb, 0.008 Al, 0.004 S, and trace Pb (calculated composition); electrical resistivity 51.4 $\mu\Omega$ cm.
82*	143	Fairbank, H.A. and Lee, D.M.	1960	L	0.28-4.0	Cupronickel	69.60	30.0	0.40 Fe; nominal composition; supplied by Anaconda; drawn into 0.0622 in. O.D. and 0.0567 in. I.D.
83	143	Mikryukov, V.Ye.	1958	E	340-827		Bal.	0.7	0.15 Co, 0.15 Fe, 0.1 Be, and 0.1 C; electrical resistivity 3.99, 4.29, 5.01, 5.60, 5.98, 6.37, 6.93, 7.55, and 9.32 $\mu\Omega$ cm at 65, 115, 196, 275, 380, 440, 511, 589, and 700 C, respectively.
84	73	Erdmann, J.C. and Jahoda, J.A.	1964	L	4.2	667	Bal.	27.96	<1.0 each Mn, Mg, Fe, and 0.023 Al; polycrystalline; wire specimen 1.35 to 1.45 mm in diameter and 125 mm long; obtained from International Nickel Co.; vacuum cast ingot hammer forged, hot rolled to 18.5 mm diameter, rough turned, cold rolled to 6 mm diameter and drawn to 1.5 mm diameter, cut; annealed at 1000 C for 24 hr, cooled slowly in the furnace over a period of 6 hr, electropolished; electrical resistivity 32.3 $\mu\Omega$ cm at 4.2 K.
85	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 39	79.68	19.79	0.30 Mn and 0.23 Fe; 0.75 in. diameter and 8 in. long; cold-rolled to 1.25 in. in diameter, annealed, cold-drawn to size; heat-treated at 800 C; electrical conductivity 3.755 and 3.600 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
86	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 66	96.06	3.01	0.88 Si and 0.04 Fe; 0.75 in. diameter and 8 in. long; cold-rolled to 1.25 in. in diameter, annealed, cold-drawn to size; heat-treated at 870 C for 3 hr, quenched; electrical conductivity 9.775 and 9.140 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
87	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 66A			Similar to the above specimen except reheated after quenching at 500 C for 2 hr; electrical conductivity 20.69 and 16.38 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
88	49	Smith, C.S. and Palmer, E.W.	1935	L	293,473	Bar 66B			Similar to the above specimen bar 66 (Curve No. 86) except cooled slowly after heat-treatment at 870 C; electrical conductivity 22.60 and 17.34 x 10^4 Ω^{-1} cm^{-1} at 20 and 200 C, respectively.
89	123	Materials in Design Engineering	1960		293.2	Cupro-nickel	68.9	30	0.6 Mn and 0.5 Fe; nominal composition; density 8.94 g cm^{-3}; electrical resistivity 37 $\mu\Omega$ cm at 20 C.
90	123	Materials in Design Engineering	1960		293.2	Cupro-nickel	88.35	10	1.25 Fe and 0.4 Mn; nominal composition; density 8.94 g cm^{-3}; electrical resistivity 15 $\mu\Omega$ cm at 20 C.
91	146	Willett, R.E.	1966	C	378-463	Copper-Nickel (706) alloy	88.08	10.07	1.18 Fe, 0.67 Mn, < 0.10 Zn, and < 0.02 Pb; annealed at 750 C and cooled by waterfall spray at the exit end of the furnace; Armco iron used as comparative material; equilibrium 1.
92	146	Willett, R.E.	1966	C	701-989	Copper-Nickel (706) alloy			The above specimen; equilibrium 2.
93	146	Willett, R.E.	1966	C	388-466	Copper-Nickel (706) alloy			The above specimen; equilibrium 3.

* Not shown in figure.

TABLE 12. THERMAL CONDUCTIVITY OF COPPER + NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
94	146	Willett, R.E.	1968	C	447-668	Copper-Nickel (706) alloy	88.08	10.07	1.18 Fe, 0.67 Mn, < 0.10 Zn, and <0.02 Pb; the above specimen; equilibrium 4.
95	146	Willett, R.E.	1968	C	557-738	Copper-Nickel (706) alloy			The above specimen; equilibrium 5.
96	146	Willett, R.E.	1968	C	391-686	Copper-Nickel (706) alloy			Similar to the above specimen except annealed at 750 C for 1 hr and water quenched.
97	146	Willett, R.E.	1968	C	377-1017	Copper-Nickel (706) alloy			Similar to the above specimen except annealed at 750 C for 1 hr and furnace cooled.
98	146	Willett, R.E.	1968	C	382-1020	Copper-Nickel (710) alloy	77.75	20.67	0.81 Fe, 0.55 Mn, 0.20 Zn, 0.01 Pb, and 0.017 C; annealed at 750 C and cooled by waterfall spray at the exit end of the furnace; Armco iron used as comparative material.
99	146	Willett, R.E.	1968	C	406-927	Copper-Nickel (715) alloy; 1	68.33	30.72	0.53 Fe, 0.41 Mn, < 0.10 Zn, 0.028 C, and <0.006 Pb; annealed at 650 C and cooled by waterfall spray at the exit end of the furnace; Armco iron used as comparative material.
100	146	Willett, R.E.	1968	C	365-949	Copper-Nickel (715) alloy; 2	69.29	30.87	0.59 Mn, 0.51 Fe, 0.38 C, <0.10 Zn, and 0.086 Pb; similar to the above specimen except annealed at 750 C.
101	146	Willett, R.E.	1968	C	365-948	Copper-Nickel (715) alloy	68.40	29.94	0.62 Fe, 0.50 Zn, 0.46 Mn, 0.063 C, and 0.010 Pb; similar to the above specimen.
102	146	Willett, R.E.	1968	C	380-991	Copper-Nickel (715) alloy	68.60	29.94	0.61 Fe, 0.48 Mn, 0.30 Zn, 0.059 C, and 0.007 Pb; similar to the above specimen except annealed at 1000 C and water quenched.
103	76	Bouley, A., Linz, R., Khaffey, R., Damon, D.H., and Mohan, N.S.	1974		11-40			3.71	Calculated composition from atomic percent; annealed at 1075 ± 5 C for 72 hrs and slowly cooled afterwards in 18 hrs; residual electrical resistivity reported as 4.92 $\mu\Omega$ cm.
104	76	Bouley, A., et al.	1974		10-41			3.71	Calculated composition from atomic percent; heavily swaged; residual electrical resistivity reported as 4.54 $\mu\Omega$ cm.

TABLE 13. THERMAL CONDUCTIVITY OF NICKEL - COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Cu	Composition (continued), Specifications, and Remarks
1	77	Sager, G.F.	1930	P	325-970		60	40	0.2 Mn and 0.17 Mg; 2 mm diameter and 35 cm long; prepared from Mond nickel by fusing, chill-casting, hot-rolling, and cold-drawing; annealed at 700 C for 12 hr; density 8.81 g cm^{-3}; electrical conductivity 1.89, 1.86, 1.85, 1.82, 1.81, 1.78, 1.76, 1.75, and 1.72 x 10^4 Ω^{-1} cm^{-1} at 26, 133, 204, 386, 467, 580, 642, 690, and 756 C, respectively; thermal conductivity values calculated from measured thermal diffusivity, specific heat capacity, and density.
2	77	Sager, G.F.	1930	P	317-966		80	20	Similar to above except density 8.82 g cm^{-3} and electrical conductivity 3.60, 3.06, 2.90, 2.72, 2.67, 2.48, 2.40, 2.33, 2.27, 2.22, 2.17, 2.12, 2.04, 1.97, and 1.92 x 10^4 Ω^{-1} cm^{-1} at 26, 76, 91, 128, 131, 164, 184, 231, 291, 331, 396, 451, 546, 668, and 744 C, respectively.
3	45	Smith, A.W.	1925	L	330		80	20	Prepared by fusing Ni (99.75 to 99.85 pure); supplied by International Nickel Co., and 99.97⁺ pure Cu, supplied by Baker; ~5.5 cm long and 0.3 cm^2 in cross-sectional area; electrical conductivity 3.60 x 10^4 Ω^{-1} cm^{-1} at 25 C.
4	45	Smith, A.W.	1925	L	330		70	30	Similar to the above specimen except electrical conductivity 2.17 x 10^4 Ω^{-1} cm^{-1} at 25 C.
5	45	Smith, A.W.	1925	L	330		60	40	Similar to the above specimen except electrical conductivity 2.02 x 10^4 Ω^{-1} cm^{-1} at 25 C.
6	45	Smith, A.W.	1925	L	330		50	50	Similar to the above specimen except electrical conductivity 1.98 x 10^4 Ω^{-1} cm^{-1} at 25 C.
7	63	Sedström, E.	1919	T	273, 373		60.93	39.07	Rolled and drawn; annealed at close to melting point for 0.5 hr.
8	63	Sedström, E.	1919	T	273, 373		81.63	18.37	Similar to the above specimen.
9	78	Greig, D. and Harrison, J.P.	1965	E	1.6-111	C		0.65	Cylindrical specimen, 4 mm in diameter; calculated composition from atomic composition; supplied by Johnson Matthey and Co.; chill cast from J.M. 890 Ni and J.M. 30 Cu; annealed at 850 C for 12 hr; small grains; very fine grain boundaries; electrical resistivities are estimated from reported Lorenz number L and thermal conductivity k as 0.504, 0.594, 0.582, 0.625, 0.622, 0.636, 0.638, 0.654, 0.664, 0.679, 0.695, 0.669, 0.688, 0.707, 0.694, 0.706, 0.736, 0.738, 0.764, 0.782, 0.809, and 0.830 μΩ cm at 1.6, 2.5, 4.4, 6.4, 8.3, 10.3, 12.3, 14.9, 16.2, 17.9, 19.7, 20.3, 22.2, 24.4, 25.6, 29.6, 32.2, 35.1, 37.4, 40.6, 42.5, and 45.3 K, respectively.
10	78	Greig, D. and Harrison, J.P.	1965	E	1.6-107	D		1.62	Similar to the above specimen; long grains running in one direction, very thick (~0.05 mm) grain boundaries; electrical resistivities are estimated from reported Lorenz number L and thermal conductivity k as 0.963, 1.006, 1.115, 1.290, 1.209, 1.336, 1.442, 1.327, 1.445, 1.425, 1.408, 1.407, 1.471, 1.467, 1.512, 1.551, 1.636, 1.812, 2.097, 2.297, and 2.032 μΩ cm at 1.6, 2.4, 5.2, 7.6, 10.2, 12.5, 15.1, 16.2, 18.9, 20.7, 22.6, 26.7, 30.5, 35.3, 40.2, 45.4, 56.4, 69.3, 80.4, 90.2, and 101.7 K, respectively.

TABLE 13. THERMAL CONDUCTIVITY OF NICKEL + COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Cu	Composition (continued), Specifications, and Remarks
11	78	Greig, D. and Harrison, J.P.	1965	E	2.3-82.1	E		4.53	Similar to the above specimen; various sizes of grain; various thickness of grain boundaries; electrical resistivities are estimated from reported Lorenz number L and thermal conductivity k as 2.997, 4.318, 3.344, 3,337, 3.804, 3.757, 3.766, 3.912, 5.086, 4.963, 4.422, 4.376, 4.361, 4.166, 4.268, 4.366, 4.211, 4.190, 4.086, 4.129, 4.286, 4.098, 4.989 μΩ cm at 2.3, 3.2, 4.6, 6.5, 8.6, 10.6, 12.5, 14.4, 16.4, 16.3, 18.5, 20.1, 22.4, 24.4, 26.1, 30.6, 35.0, 40.4, 45.2, 50.2, 61.7, 70.1, and 82.1 K, respectively.
12	78	Greig, D. and Harrison, J.P.	1965	E	2.0-111	F		0.35	Similar to the above specimen; mostly small grains, but few long grains running from center; electrical resistivities are estimated from reported Lorenz number L and thermal conductivity k as 0.219, 0.190, 0.225, 0.224, 0.220, 0.225, 0.230, 0.227, 0.228, 0.244, 0.244, 0.250, 0.255, 0.264, 0.289, 0.326, 0.361, 0.414, 0.541, 0.712, 0.873, 1.084, and 1.323 μΩ cm at 2.6, 4.4, 6.7, 8.7, 10.4, 12.3, 14.6, 16.7, 18.2, 20.3, 23.3, 25.8, 28.0, 25.8, 28.0, 30.1, 35.2, 40.9, 45.5, 51.0, 62.1, 71.8, 81.3, 90.3, and 100.8 K, respectively.
13	74	Erdmann, J.C. and Jahoda, J.A.	1968	-	4.2-45	Cu 49	50.50	49.47	0.030 Al; polycrystalline; 5.0 mm diameter and 10 cm long; supplied by International Nickel Co., Inc; vacuum cast ingot hammer forged, hot-cast rolled to 18 mm diameter and rough turned; swaged to 10 mm diameter, and machined to size; annealed at 930 C for 24 hr in argon furnace and cooled slowly; residual electrical resistivity 48.10 μΩ cm; measured in a vacuum of 10^{-6} mm Hg.
14	74	Erdmann, J.C. and Jahoda, J.A.	1968	-	4.2-65	Ni 65	64.87	Bal.	0.051 Al; similar to above except residual electrical resistivity 27.62 μΩ cm.
15	74	Erdmann, J.C. and Jahoda, J.A.	1968	-	4.2-53	Ni 85	84.70	Bal.	0.054 Al; similar to above except residual electrical resistivity 11.14 μΩ cm.
16	74	Erdmann, J.C. and Jahoda, J.A.	1968	-	4.2-39	Ni 90	90.24	Bal.	0.060 Al; similar to above except residual electrical resistivity 8.24 μΩ cm.
17	74	Erdmann, J.C. and Jahoda, J.A.	1968	-	4.2-61	Ni 91	91.05	Bal.	0.046 Al; similar to above except residual electrical resistivity 15.88 μΩ cm.
18	74	Erdmann, J.C. and Jahoda, J.A.	1968	-	4.3-42	Ni 96	95.60	Bal.	Similar to above except residual electrical resistivity 3.91 μΩ cm.
19	74	Erdmann, J.C. and Jahoda, J.A.	1968	-	4.2-28	Ni 98	98.35	Bal.	Single crystal; 6.0-7.5 mm in diameter and 12 cm long; supplied by Materials Research Corp; prepared by electron beam float zoning; residual electrical resistivity 0.907 μΩ cm; measured in a vacuum of 10^{-6} mm Hg.
20	147	Jackson, P.J. and Saunders, N.H.	1968		514-614		Bal.	8.7	Polycrystalline; prepared from 4 N purity Ni and Cu; annealed; Curie point 278 C.
21	73	Erdmann, J.C. and Jahoda, J.A.	1964	L	4.2	131	Bal.	2.03	Polycrystalline; wire specimen 1.35 to 1.45 mm in diameter and 125 mm long; obtained from International Nickel Co.; vacuum cast ingot hammer forged, hot-rolled to 18.5 mm in diameter, rough turned, cold rolled to 6 mm diameter and drawn to 1.5 mm diameter, cut; annealed at 1000 C for 24 hr, slowly cooled in the furnace for a period of 6 hr, electro-polished; grain size 50 to 250 μ; electrical resistivity 1.66 μΩ cm at 4.2 K.

TABLE 13. THERMAL CONDUCTIVITY OF NICKEL - COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Cu	Composition (continued), Specifications, and Remarks
22	73	Erdmann, J.C. and Jahoda, J.A.	1964	L	4.2	670	84.7	Bal.	< 0.1 each of Fe and Mn, 0.054 Al, and 0.02 C; polycrystalline; same supplier and fabrication method as the above specimen; electrical resistivity 10.64 μΩ cm at 4.2 K.
23	73	Erdmann, J.C. and Jahoda, J.A.	1964	L	4.2	669	64.87	Bal.	0.051 Al, 0.013 C, and < 0.01 Fe; polycrystalline; same supplier and fabrication method as the above specimen; electrical resistivity 27.8 μΩ cm at 4.2 K.
24	148	Burger, R., Dittrich, H., and Koch, K.M.	1968	E	316.2		95	5	Prepared from 99.98 pure nickel; measured in transverse magnetic fields ranging from 0.48 to 10.63 kOe; reported data taken from smooth curve.
25	148	Burger, R., et al.	1968	E	316.2				The above specimen measured in longitudinal magnetic fields ranging from 0.16 to 10.59 kOe; smoothed values reported.
26	148	Burger, R., et al.	1968	E	316.2		90	10	Prepared from 99.98 pure nickel; measured in transverse magnetic fields ranging from 0.49 to 10.48 kOe; smoothed values reported.
27	148	Burger, R., et al.	1968	E	316.2				The above specimen measured in longitudinal magnetic fields ranging from 0.17 to 10.48 kOe; smoothed values reported.
28	148	Burger, R., et al.	1968	E	316.2		85	15	Prepared from 99.98 pure nickel; measured in transverse magnetic fields ranging from 0.47 to 10.50 kOe; smoothed values reported.
29	148	Burger, R., et al.	1968	E	316.2				The above specimen measured in longitudinal magnetic fields ranging from 0.19 to 10.47 kOe; smoothed values reported.
30	148	Burger, R., et al.	1968	E	316.2		80	20	Prepared from 99.98 pure nickel; measured in transverse magnetic fields ranging from 0.45 to 10.39 kOe; smoothed values reported.
31	148	Burger, R., et al.	1968	E	316.2				The above specimen measured in longitudinal magnetic fields ranging from 0.29 to 10.42 kOe; smoothed values reported.
32	148	Burger, R., et al.	1968	E	316.2		75	25	Prepared from 99.98 pure nickel; measured in transverse magnetic fields ranging from 0.48 to 10.34 kOe; smoothed values reported.
33	148	Burger, R., et al.	1968	E	316.2				The above specimen measured in longitudinal magnetic fields ranging from 0.33 to 10.46 kOe; smoothed values reported.
34	81	Farrell, T. and Greig, D.	1969	L	3.4-90			0.34	~3 mm diameter and 9 cm long; supplied by Metals Research Ltd.; annealed at 850 C for 15 hr; residual electrical resistivity 0.247 μΩ cm; electrical resistivity 6.67 μΩ cm at 0 C.
35	149	Berger, L.	1969	L	1.7-4.3		Bal.	35	Polycrystalline from Johnson Matthey Ni and Cu, vacuum melted, swaged, homogenized for 48 hr at 1200 C in purified helium, and furnace cooled.
36	149	Berger, L.	1969	L	1.5-4.3				The above specimen measured in a constant longitudinal field of 58.9 kG.
37	186, 177	Yelon, W.B. and Berger, L.	1970	L	1.6-4.3			33.4	Prepared by melting high-purity Johnson Matthey metal in a vacuum of 6×10^{-6} torr, after cooling, machining to round rod, homogenizing at 1300 C for 2400 hr, in helium, annealing in a vacuum of 10^{-5} torr at 1000 C for 0.5 hr, swaging to 0.797 cm in diameter, again annealing in a vacuum of 6×10^{-6} torr at 750 C for 1 hr; grain size 0.1~0.5 mm; electrical resistivity 23.4 μΩ cm at 4.2 K; run 7.
38	186, 177	Yelon, W.G. and Berger, L.	1970	L	1.7-4.3				The above specimen; run 8.

TABLE 13. THERMAL CONDUCTIVITY OF NICKEL + COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Cu	Composition (continued), Specifications, and Remarks
39	166, 177	Yelon, W.B. and Berger, L.	1970	L	2.3-21				The above specimen measured in a parallel magnetic field of 58.96 kG; run 10.
40	166, 177	Yelon, W.B. and Berger, L.	1970	L	1.4-2.1				The above specimen measured without the magnetic field; run 11.
41	166, 177	Yelon, W.B. and Berger, L.	1970	L	1.4-4.3				The above specimen; run 9.
42	166, 177	Yelon, W.B. and Berger, L.	1970	L	2.1-21				The above specimen; run 12.
43	150	Donaldson, J.W.	1939	L	353-701	"K" Monel	66.73	29.76	2.50 Al, 0.35 Fe, 0.25 Si, 0.20 C, and 0.21 Mn; rolled and annealed.
44	134	Aoyama, S. and Ito, T.	1940	L	78	No. 0	94.77	4.36	0.51 Co, 0.26 Mn, 0.08 Fe, 0.02 Al, 0.001 Sb, 0.0004 S, and trace Pb (calculated composition); 4.00 mm diameter and 60.0 mm long; cast, hot-rolled, then machined to size; electrical resistivity 5.00 $\mu\Omega$ cm at 78 K.
45	134	Aoyama, S. and Ito, T.	1940	L	78	No. 1	90.43	8.85	0.48 Co, 0.13 Mn, 0.09 Fe, 0.02 Al, 0.001 Sb, 0.0007 S, and trace Pb (calculated composition); 4.00 mm diameter and 60.0 mm long; cast, hot-rolled, machined to size; electrical resistivity 8.50 $\mu\Omega$ cm at 78 K.
46	134	Aoyama, S. and Ito, T.	1940	L	78	No. 2	85.62	13.71	0.46 Co, 0.10 Mn, 0.094 Fe, 0.017 Al, 0.002 Sb, 0.001 S, and trace Pb (calculated composition); 4.00 mm diameter and 60.0 mm long; cast, hot-rolled, machined to size; electrical resistivity 12.2 $\mu\Omega$ cm at 78 K.
47	134	Aoyama, S. and Ito, T.	1940	L	78	No. 3	77.73	21.69	0.414 Co, 0.091 Fe, 0.05 Mn, 0.015 Al, 0.003 Sb, 0.0015 S, and trace Pb (calculated composition); 4.00 mm diameter and 60.0 mm long; cast, hot-rolled, machined to size; electrical resistivity 18.1 $\mu\Omega$ cm at 78 K.
48	134	Aoyama, S. and Ito, T.	1940	L	78	No. 4	69.14	30.35	0.37 Co, 0.05 Si, 0.068 Fe, 0.014 Al, 0.005 Sb, 0.0021 S, and trace Pb (calculated composition); 4.00 mm diameter and 60.0 mm long; cast, hot-rolled, machined to size; electrical resistivity 28.0 $\mu\Omega$ cm at 78 K.
49	134	Aoyama, S. and Ito, T.	1940	L	78	No. 5	58.98	40.53	0.314 Co, 0.104 Fe, 0.012 Al, 0.04 Mn, 0.006 Sb, 0.0028 S, and trace Pb (calculated composition); 4.00 mm diameter and 60.0 mm long; cast, hot-rolled, machined to size; electrical resistivity 47.7 $\mu\Omega$ cm at 78 K.

4.5. Copper-Palladium Alloy System

The copper-palladium system forms a continuous series of solid solutions over the entire range of compositions. Ordered structures are formed at temperatures below about 775 K for compositions ranging from slightly below 10 to somewhat above 25 At.% (16 to 36%) palladium and at temperatures below about 975 K for compositions ranging from slightly below 30 to somewhat above 50 At.% (42 to 63%) palladium. The maxima of the temperatures of transformation suggest that these ordered structures are based on $PdCu_5$ and Pd_3Cu_5 respectively. In this connection, it should be noted that curves 2 and 3 of the Cu + Pd alloys and curves 3, 5, 6, 12, 13, 14, 15, 22, 23, 24, and 25 of the Pd + Cu alloys are values obtained from specimens which were in a partially ordered state.

There are 49 sets of experimental data available for the thermal conductivity of this alloy system. However, of the 19 data sets available for Cu + Pd alloys listed in Table 15 and shown in Figure 23, 14 sets are merely single data points around room temperature, and of the 30 data sets for Pd + Cu alloys listed in Table 16 and shown in Figure 24, 19 sets are single data points around room temperature.

The thermal conductivity of these alloys was first investigated by Sedström [178, 179] who measured the thermal conductivity at 273 K of 14 specimens ranging from 3.5 to 93% Pd and the thermal conductivity at 323 K of 17 specimens ranging from 8.41 to 93.19% Pd. Later Grüneisen and Reddemann [61] measured the low temperature thermal conductivity of specimens containing 10.3, 57.8, 62.7, and 90.8% Pd (Cu + Pd curve 1 and Pd + Cu curves 1-5) and it was found that prolonged annealing just below the order-disorder transition temperature produced a 6-fold increase in the thermal conductivity at 80 K of the specimen containing 57.8% Pd. More recently, Pott [82] measured the thermal conductivity of specimens containing 24.18, 35.82, 52.75, 57.81, and 70.67% Pd at temperatures ranging from 293 to 1073 K. The first four specimens were measured both in the disordered state and after prolonged annealing just below the transition temperature (Cu + Pd curves 2-5 and Pd + Cu curves 6, 7, 9, and 10); the specimen containing 70.67% Pd was measured following two different heat treatments (Pd + Cu curves 8 and 10). The most recent measurement on alloys of this system was made in 1967 by Kierspe [83] (Cu + Pd curve 6) for a specimen containing 4.92% Pd at room temperature.

The low temperature experimental thermal conductuvity values for disordered specimens are in satisfactory agreement with the values calculated from eqs. (12) and (35) for those compositions for which the k_g maximum occurs below 80 K. The investigation by Fletcher and Grieg [84] of the lattice thermal conductivity of palladium-silver alloys showed that the strong electron-phonon interaction in the palladium-rich alloys reduces the low temperature lattice thermal conductivity, causing its maximum to occur at much higher temperatures than in the silver-rich alloys. A similar elevation of the temperature of the

maximum of the lattice component is believed to occur in this alloy system. The discrepancy between the experimental and calculated values of the thermal conductivity at 80 K ranged from 2 to 12%, the calculated values being higher; the 12% discrepancy was with the specimen containing 57.8% Pd and the electrical resistivities reported for this specimen are 8% greater than those reported by other authors for this composition.

At ordinary temperatures Sedström's values for his disordered specimens tend to be lower than the calculated values, particularly for the more dilute alloys; this is not surprising in view of the fact that the electrical resistivities of these specimens are higher than those reported by other authors for the same nominal compositions. In this same temperature range the calculated values are within 3% of Kierspe's value for a specimen containing 4.9% Pd and Pott's value for a specimen containing 57.8% Pd. On the other hand, the calculated values were 16% below Pott's value for a specimen containing 24.18% Pd and 28% below his value for a specimen containing 70.67% Pd. After correcting for the lattice component, corresponding Lorenz ratios for these specimens are respectively 22 and 36% greater than the classical value; it is unlikely that band structure effects could cause such large deviations from the classical value for these alloys at 300 K.

At higher temperatures there are four large discrepancies between the calculated and experimental values, ranging from 30 to 40%. Three of these are with the 70.67% Pd specimen mentioned above and are associated with Lorenz ratios 33 to 38% greater than the classical value; the other discrepancy is with Pott's specimen containing 57.8% Pd and the corresponding Lorenz ratio is 36% greater than the classical value. While heavy alloying with a noble element would presumably reduce band structure effects, these Lorenz ratios are larger than those obtained by Laubitz and Matsumura [10] for pure palladium. Also, they are very much larger than those obtained by Laubitz and van der Meer [85] for a gold alloy with 34.95% Pd in which comparable band structure effects might be expected. Further experimental work on the palladium-rich alloys of this system is clearly in order. Until there is additional experimental evidence or some theoretical support for these very large Lorenz ratios it seems safer to use evidence from similar systems rather than the thermal conductivities associated with these Lorenz ratios as a guide in recommending values.

The recommended values for k, k_e, and k_g are tabulated in Table 14 for 25 alloy compositions. These values are for well-annealed disordered alloys. The values for k are also shown in Figures 21 and 22. The k_e values cover the full temperature range from 4 to 1200 K, but k and k_g values are not given at very low temperatures. The values of residual electrical resistivity for the alloys are also given in Table 14. The uncertainties of the k values are stated in a footnote to Table 14, and those of the k_e and k_g values are of the order of ±10 to ±15%.

TABLE 14. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER–PALLADIUM ALLOY SYSTEM†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 99.50% (99.70 At.%) Pd: 0.50% (0.30 At.%)				Cu: 99.00% (99.40 At.%) Pd: 1.00% (0.60 At.%)				Cu: 97.00% (98.19 At.%) Pd: 3.00% (1.81 At.%)				Cu: 95.00% (96.95 At.%) Pd: 5.00% (3.05 At.%)			
ρ_0 = 0.2900 μΩcm				ρ_0 = 0.580 μΩcm				ρ_0 = 1.620 μΩcm				ρ_0 = 2.700 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.349		4		0.168		4		0.0603		4		0.0362	
6		0.524		6		0.253		6		0.0905		6		0.0543	
8		0.698		8		0.337		8		0.121		8		0.0724	
10		0.873		10		0.421		10		0.151		10		0.0905	
15		1.31		15		0.632		15		0.226		15		0.136	
20		1.75		20		0.842		20		0.302		20		0.181	
25		2.06		25		1.04		25		0.376		25		0.226	
30		2.44		30		1.24		30		0.450		30		0.270	
40		3.11		40		1.59		40		0.591		40		0.359	
50	3.60*	3.36	0.234	50	2.15*	1.87	0.277	50	0.917*	0.713	0.204	50	0.615*	0.442	0.173
60	3.59*	3.27	0.316	60	2.25*	1.98	0.267	60	1.01*	0.820	0.194	60	0.680*	0.516	0.163
70	3.45*	3.14	0.307	70	2.29*	2.04	0.258	70	1.09*	0.905	0.184	70	0.736*	0.582	0.155
80	3.31*	3.01	0.297	80	2.29*	2.05	0.248	80	1.15*	0.975	0.176	80	0.791*	0.644	0.147
90	3.26*	2.97	0.286	90	2.35*	2.11	0.239	90	1.22*	1.05	0.168	90	0.845*	0.705	0.140
100	3.25*	2.98	0.275	100	2.41*	2.18	0.229	100	1.28*	1.12	0.161	100	0.895*	0.761	0.134
150	3.31*	3.09	0.226	150	2.72*	2.53	0.190	150	1.60*	1.46	0.133	150	1.15*	1.04	0.110
200	3.46*	3.27	0.188	200	2.90*	2.74	0.161	200	1.83*	1.71	0.114	200	1.35*	1.26	0.0947
250	3.49*	3.32	0.169	250	3.06*	2.91	0.139	250	2.03*	1.93	0.100	250	1.53*	1.45	0.0834
273	3.55*	3.40	0.150	273	3.08*	2.95	0.131	273	2.11*	2.02	0.0949	273	1.61	1.53	0.0792
300	3.54*	3.40	0.140	300	3.16*	3.04	0.122	300	2.24*	2.15	0.0895	300	1.69	1.61	0.0748
350	3.56*	3.44	0.123	350	3.22*	3.12	0.109	350	2.31*	2.23	0.0811	350	1.82	1.75	0.0681
400	3.56*	3.45	0.110	400	3.30*	3.20	0.0987	400	2.42*	2.35	0.0743	400	1.93*	1.86	0.0626
500	3.64*	3.55	0.0913	500	3.33*	3.27	0.0828	500	2.60*	2.54	0.0638	500	2.15*	2.09	0.0542
600	3.58*	3.50	0.0778	600	3.37*	3.29	0.0713	600	2.73*	2.68	0.0561	600	2.28*	2.23	0.0481
700	3.58*	3.51	0.0677	700	3.37*	3.31	0.0627	700	2.81*	2.76	0.0502	700	2.40*	2.35	0.0433
800	3.50*	3.44	0.0599	800	3.36*	3.30	0.0559	800	2.84*	2.80	0.0455	800	2.48*	2.44	0.0395
900	3.47*	3.41	0.0538	900	3.31*	3.26	0.0505	900	2.88*	2.84	0.0416	900	2.53*	2.49	0.0363
1000	3.42*	3.37	0.0490	1000	3.29*	3.24	0.0460	1000	2.88*	2.84	0.0383	1000	2.56*	2.52	0.0337
1100	3.36*	3.32	0.0446	1100	3.26*	3.22	0.0422	1100	2.89*	2.85	0.0356	1100	2.58*	2.55	0.0314
1200	3.31*	3.27	0.0411	1200	3.21*	3.17	0.0391	1200	2.87*	2.84	0.0332	1200	2.59*	2.56	0.0294

† Uncertainties of the total thermal conductivity, k, are as follows:
99.50 Cu - 0.50 Pd: ±10%.
99.00 Cu - 1.00 Pd: ±10%.
97.00 Cu - 3.00 Pd: ±10%.
95.00 Cu - 5.00 Pd: ±10%.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 14. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 90.00% (93.78 At.%) Pd: 10.00% (6.22 At.%)				Cu: 85.00% (90.47 At.%) Pd: 15.00% (9.53 At.%)				Cu: 80.00% (87.01 At.%) Pd: 20.00% (12.99 At.%)				Cu: 75.00% (83.40 At.%) Pd: 25.00% (16.60 At.%)			
ρ_0 = 5.32 $\mu\Omega$cm				ρ_0 = 7.91 $\mu\Omega$cm				ρ_0 = 10.43 $\mu\Omega$cm				ρ_0 = 12.90 $\mu\Omega$cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.0184		4		0.0124		4		0.00937		4		0.00758	
6		0.0276		6		0.0185		6		0.0141		6		0.0114	
8		0.0367		8		0.0247		8		0.0187		8		0.0152	
10		0.0459		10		0.0309		10		0.0234		10		0.0189	
15		0.0689		15		0.0463		15		0.0351		15		0.0284	
20		0.0918		20		0.0618		20		0.0468		20		0.0379	
25		0.114		25		0.0771		25		0.0585		25		0.0473	
30		0.137		30		0.0924		30		0.0702		30		0.0567	
40		0.181		40		0.123		40		0.0934		40		0.0755	
50	0.360	0.225	0.136	50	0.267*	0.152	0.115	50	0.218*	0.116	0.102	50	0.186*	0.0939	0.0925
60	0.393	0.267	0.126	60	0.288*	0.181	0.107	60	0.233*	0.138	0.0945	60	0.198*	0.112	0.0857
70	0.424	0.305	0.119	70	0.308*	0.208	0.100	70	0.249*	0.160	0.0886	70	0.210*	0.130	0.0802
80	0.455	0.343	0.112	80	0.329*	0.234	0.0947	80	0.265*	0.181	0.0835	80	0.223*	0.147	0.0756
90	0.486	0.379	0.107	90	0.351*	0.261	0.0899	90	0.281*	0.202	0.0792	90	0.236*	0.164	0.0717
100	0.516*	0.414	0.102	100	0.373*	0.287	0.0857	100	0.299*	0.223	0.0755	100	0.249*	0.181	0.0682
150	0.649*	0.585	0.0637	150	0.484*	0.414	0.0703	150	0.386*	0.324	0.0618	150	0.321*	0.265	0.0558
200	0.815*	0.743	0.0719	200	0.593*	0.533	0.0604	200	0.472*	0.419	0.0532	200	0.393*	0.345	0.0480
250	0.930*	0.867	0.0636	250	0.698*	0.644	0.0534	250	0.557*	0.510	0.0471	250	0.465*	0.422	0.0425
273	1.01	0.945	0.0604	273	0.742	0.691	0.0509	273	0.594	0.549	0.0448	273	0.496	0.456	0.0405
300	1.07	1.01	0.0572	300	0.796	0.748	0.0482	300	0.638	0.596	0.0425	300	0.533	0.494	0.0384
350	1.18	1.13	0.0522	350	0.886	0.842	0.0441	350	0.715	0.676	0.0389	350	0.599	0.564	0.0352
400	1.29*	1.24	0.0462	400	0.971*	0.930	0.0408	400	0.787*	0.751	0.0360	400	0.662	0.629	0.0326
500	1.47*	1.43	0.0421	500	1.13*	1.10	0.0357	500	0.924*	0.893	0.0316	500	0.782	0.753	0.0287
600	1.63*	1.59	0.0375	600	1.27*	1.24	0.0319	600	1.05*	1.02	0.0283	600	0.895	0.869	0.0257
700	1.77*	1.73	0.0340	700	1.40*	1.37	0.0290	700	1.17*	1.14	0.0258	700	1.00	0.979	0.0235
800	1.88*	1.85	0.0312	800	1.51*	1.48	0.0267	800	1.27*	1.25	0.0238	800	1.10	1.08	0.0216
900	1.97*	1.94	0.0289	900	1.61*	1.58	0.0248	900	1.36*	1.34	0.0221	900	1.19	1.17	0.0201
1000	2.04*	2.01	0.0270	1000	1.68*	1.66	0.0232	1000	1.45*	1.43	0.0207	1000	1.27	1.25	0.0189
1100	2.09*	2.07	0.0253	1100	1.75*	1.73	0.0218	1100	1.52*	1.50	0.0195	1100	1.35*	1.33	0.0178
1200	2.14*	2.11	0.0238	1200	1.80*	1.78	0.0206	1200	1.58*	1.56	0.0184	1200	1.42*	1.40	0.0168

† Uncertainties of the total thermal conductivity, k, are as follows:

90.00 Cu - 10.00 Pd: ±10%.
85.00 Cu - 15.00 Pd: ±10%.
80.00 Cu - 20.00 Pd: ±10%.
75.00 Cu - 25.00 Pd: ±10%.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 14. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM (continued) †

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 70.00% (79.62 At.%) Pd: 30.00% (20.38 At.%)				Cu: 65.00% (75.67 At.%) Pd: 35.00% (24.33 At.%)				Cu: 60.00% (71.52 At.%) Pd: 40.00% (23.48 At.%)				Cu: 55.00% (67.18 At.%) Pd: 45.00% (32.82 At.%)			
ρ_o = 15.30 μΩcm				ρ_o = 17.68 μΩcm				ρ_o = 20.01 μΩcm				ρ_o = 22.60 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.00639		4		0.00553		4		0.00488		4		0.00432	
6		0.00958		6		0.00829		6		0.00733		6		0.00649	
8		0.0128		8		0.0111		8		0.00977		8		0.00865	
10		0.0160		10		0.0138		10		0.0122		10		0.0108	
15		0.0240		15		0.0207		15		0.0183		15		0.0162	
20		0.0319		20		0.0276		20		0.0244		20		0.0216	
25		0.0399		25		0.0345		25		0.0305		25		0.0270	
30		0.0478		30		0.0414		30		0.0366		30		0.0324	
40		0.0636		40		0.0551		40		0.0487		40		0.0431	
50	0.165*	0.0791	0.0855	50	0.149*	0.0688	0.0799	50	0.136*	0.0606	0.0756	50	0.126*	0.0537	0.0721
60	0.174*	0.0945	0.0791	60	0.156*	0.0822	0.0739	60	0.142*	0.0724	0.0696	60	0.131*	0.0642	0.0665
70	0.183*	0.109	0.0739	70	0.164*	0.0953	0.0691	70	0.149*	0.0840	0.0652	70	0.137*	0.0745	0.0621
80	0.194*	0.125	0.0696	80	0.173*	0.108	0.0650	80	0.157*	0.0955	0.0613	80	0.143*	0.0847	0.0584
90	0.205*	0.139	0.0660	90	0.183*	0.121	0.0615	90	0.165*	0.107	0.0580	90	0.150*	0.0948	0.0553
100	0.217*	0.154	0.0628	100	0.193*	0.134	0.0585	100	0.173*	0.118	0.0552	100	0.158*	0.105	0.0526
150	0.278*	0.226	0.0514	150	0.246*	0.198	0.0479	150	0.219*	0.174	0.0451	150	0.198*	0.155	0.0429
200	0.339*	0.295	0.0442	200	0.300*	0.259	0.0412	200	0.267*	0.229	0.0388	200	0.240*	0.203	0.0369
250	0.401*	0.362	0.0392	250	0.354*	0.317	0.0365	250	0.316*	0.281	0.0344	250	0.283*	0.250	0.0328
273	0.428*	0.391	0.0373	273	0.378	0.344	0.0348	273	0.338	0.305	0.0328	273	0.302	0.271	0.0312
300	0.462*	0.426	0.0354	300	0.407	0.374	0.0330	300	0.363	0.332	0.0311	300	0.325	0.296	0.0297
350	0.520*	0.487	0.0325	350	0.459	0.428	0.0303	350	0.410	0.381	0.0286	350	0.367	0.340	0.0272
400	0.575*	0.545	0.0301	400	0.509	0.481	0.0281	400	0.454*	0.428	0.0265	400	0.407*	0.382	0.0252
500	0.683*	0.657	0.0264	500	0.606	0.583	0.0247	500	0.542*	0.519	0.0233	500	0.485*	0.463	0.0222
600	0.826*	0.802	0.0238	600	0.701	0.678	0.0222	600	0.627*	0.606	0.0210	600	0.561*	0.541	0.0200
700	0.882*	0.860	0.0217	700	0.790*	0.770	0.0203	700	0.707*	0.688	0.0192	700	0.633*	0.615	0.0183
800	0.972*	0.952	0.0200	800	0.873	0.854	0.0187	800	0.782*	0.764	0.0177	800	0.701*	0.685	0.0169
900	1.05*	1.04	0.0186	900	0.948	0.931	0.0175	900	0.853*	0.837	0.0165	900	0.765*	0.749	0.0157
1000	1.13*	1.11	0.0175	1000	1.02	1.00	0.0164	1000	0.920*	0.904	0.0155	1000	0.825*	0.810	0.0148
1100	1.20*	1.18	0.0165	1100	1.09	1.07	0.0154	1100	0.982*	0.967	0.0146	1100	0.881*	0.867	0.0140
1200	1.26*	1.25	0.0156	1200	1.15*	1.14	0.0146	1200	1.04*	1.03	0.0139	1200	0.933*	0.920	0.0132

† Uncertainties of the total thermal conductivity, k, are as follows:

70.00 Cu - 30.00 Pd: ±10%.
65.00 Cu - 35.00 Pd: ±10%.
60.00 Cu - 40.00 Pd: ±10%.
55.00 Cu - 45.00 Pd: ±10%.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 14. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER–PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 50.00% (62.61 At.%) Pd: 50.00% (37.39 At.%)				Cu: 45.00% (57.81 At.%) Pd: 55.00% (42.19 At.%)				Cu: 40.00% (52.75 At.%) Pd: 60.00% (47.25 At.%)				Cu: 35.00% (47.41 At.%) Pd: 65.00% (52.59 At.%)			
ρ_0 = 25.53 $\mu\Omega$cm				ρ_0 = 29.00 $\mu\Omega$cm				ρ_0 = 32.63 $\mu\Omega$cm				ρ_0 = 40.00 $\mu\Omega$cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.00383		4		0.00337		4		0.00300		4		0.00244	
6		0.00574		6		0.00505		6		0.00449		6		0.00366	
8		0.00766		8		0.00674		8		0.00599		8		0.00489	
10		0.00957		10		0.00842		10		0.00749		10		0.00611	
15		0.0144		15		0.0126		15		0.0112		15		0.00916	
20		0.0191		20		0.0168		20		0.0150		20		0.0122	
25		0.0239		25		0.0210		25		0.0186		25		0.0152	
30		0.0287		30		0.0252		30		0.0223		30		0.0182	
40		0.0381		40		0.0336		40		0.0296		40		0.0242	
50	0.117*	0.0476	0.0693	50		0.0419		50		0.0369		50		0.0301	
60	0.121*	0.0568	0.0640	60	0.112*	0.0500	0.0620	60		0.0440		60		0.0360	
70	0.126*	0.0659	0.0597	70	0.116*	0.0580	0.0578	70	0.108	0.0511	0.0565	70		0.0419	
80	0.131*	0.0750	0.0561	80	0.120	0.0660	0.0544	80	0.111	0.0582	0.0531	80	0.100	0.0477	0.0525
90	0.137*	0.0840	0.0531	90	0.125	0.0740	0.0514	90	0.115	0.0652	0.0503	90	0.103	0.0535	0.0496
100	0.143*	0.0929	0.0505	100	0.131*	0.0819	0.0489	100	0.120*	0.0722	0.0478	100	0.106*	0.0591	0.0471
150	0.178*	0.137	0.0412	150	0.161*	0.121	0.0399	150	0.145*	0.106	0.0390	150	0.126*	0.0872	0.0385
200	0.215*	0.180	0.0355	200	0.192*	0.158	0.0343	200	0.172*	0.139	0.0335	200	0.148*	0.114	0.0331
250	0.253*	0.222	0.0315	250	0.225*	0.195	0.0305	250	0.200*	0.170	0.0297	250	0.170*	0.141	0.0293
273	0.269	0.239	0.0300	273	0.240	0.211	0.0290	273	0.212	0.184	0.0283	273	0.181	0.153	0.0279
300	0.288	0.260	0.0285	300	0.257	0.230	0.0276	300	0.227	0.200	0.0269	300	0.193	0.167	0.0265
350	0.325	0.299	0.0261	350	0.289	0.263	0.0253	350	0.254	0.230	0.0247	350	0.216	0.192	0.0243
400	0.361	0.337	0.0242	400	0.320	0.296	0.0235	400	0.281	0.258	0.0229	400	0.239*	0.216	0.0226
500	0.430	0.409	0.0213	500	0.379	0.359	0.0207	500	0.333	0.312	0.0202	500	0.283*	0.263	0.0199
600	0.497	0.477	0.0192	600	0.437	0.418	0.0186	600	0.382	0.363	0.0182	600	0.325*	0.307	0.0179
700	0.561	0.543	0.0176	700	0.492	0.475	0.0170	700	0.429	0.413	0.0166	700	0.366*	0.350	0.0164
800	0.622	0.606	0.0162	800	0.545	0.529	0.0157	800	0.475	0.460	0.0154	600	0.407*	0.392	0.0151
900	0.680	0.665	0.0151	900	0.596	0.581	0.0147	900	0.520	0.506	0.0143	900	0.448*	0.433	0.0141
1000	0.734	0.720	0.0142	1000	0.645	0.631	0.0138	1000	0.563	0.549	0.0134	1000	0.488*	0.474	0.0132
1100	0.786	0.773	0.0134	1100	0.691	0.678	0.0130	1100	0.604	0.591	0.0127	1100	0.529*	0.516	0.0125
1200	0.835*	0.822	0.0127	1200	0.734*	0.722	0.0123	1200	0.643*	0.631	0.0120	1200	0.570*	0.558	0.0119

† Uncertainties of the total thermal conductivity, k, are as follows:
50.00 Cu - 50.00 Pd: ±10%.
45.00 Cu - 55.00 Pd: ±10%.
40.00 Cu - 60.00 Pd: ±10%.
35.00 Cu - 65.00 Pd: ±10%.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 14. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM (continued) †

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 30.00% (41.78 At.%) Pd: 70.00% (58.22 At.%)				Cu: 25.00% (35.82 At.%) Pd: 75.00% (64.18 At.%)				Cu: 20.00% (29.51 At.%) Pd: 80.00% (70.49 At.%)				Cu: 15.00% (22.81 At.%) Pd: 85.00% (77.19 At.%)			
ρ_0 = 44.19 μΩcm				ρ_0 = 42.40 μΩcm				ρ_0 = 36.26 μΩcm				ρ_0 = 28.68 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.00221		4		0.00231		4		0.00270		4		0.00341	
6		0.00332		6		0.00346		6		0.00404		6		0.00511	
8		0.00442		8		0.00461		8		0.00539		8		0.00682	
10		0.00553		10		0.00576		10		0.00674		10		0.00852	
15		0.00829		15		0.00864		15		0.0101		15		0.0128	
20		0.0111		20		0.0115		20		0.0135		20		0.0170	
25		0.0137		25		0.0142		25		0.0165		25		0.0207	
30		0.0165		30		0.0170		30		0.0198		30		0.0247	
40		0.0219		40		0.0226		40		0.0261		40		0.0325	
50		0.0273		50		0.0281		50		0.0323		50		0.0400	
60		0.0326		60		0.0335		60		0.0384		60		0.0473	
70		0.0379		70		0.0388		70		0.0444		70		0.0545	
80		0.0432		80		0.0441		80		0.0503		80		0.0615	
90		0.0485		90		0.0494		90		0.0561		90		0.0684	
100		0.0535		100		0.0547		100		0.0619		100		0.0752	
150	0.117*	0.0790	0.0384	150	0.119*	0.0801	0.0388	150		0.0893		150		0.107	
200	0.137*	0.104	0.0330	200	0.138*	0.105	0.0334	200	0.150*	0.115	0.0344	200	0.172*	0.136	0.0365
250	0.157*	0.128	0.0292	250	0.158*	0.129	0.0296	250	0.171*	0.140	0.0305	250	0.195*	0.163	0.0323
273	0.167	0.139	0.0279	273	0.168	0.139	0.0282	273	0.180	0.151	0.0290	273	0.206	0.175	0.0306
300	0.178	0.152	0.0264	300	0.179	0.152	0.0267	300	0.192	0.164	0.0275	300	0.218	0.189	0.0292
350	0.199	0.175	0.0243	350	0.200	0.176	0.0245	350	0.214	0.189	0.0252	350	0.242	0.215	0.0267
400	0.220	0.198	0.0225	400	0.222	0.199	0.0227	400	0.236*	0.213	0.0234	400	0.265*	0.240	0.0247
500	0.262	0.242	0.0196	500	0.264	0.244	0.0200	500	0.280*	0.259	0.0206	500	0.311*	0.289	0.0217
600	0.303	0.285	0.0178	600	0.306	0.288	0.0180	600	0.323*	0.304	0.0185	600	0.356*	0.336	0.0195
700	0.343*	0.327	0.0163	700	0.347*	0.331	0.0164	700	0.366*	0.349	0.0169	700	0.400*	0.383	0.0178
800	0.383	0.368	0.0151	800	0.388	0.373	0.0152	800	0.408*	0.393	0.0156	800	0.443*	0.427	0.0164
900	0.422	0.408	0.0140	900	0.430	0.415	0.0142	900	0.450*	0.436	0.0145	900	0.485*	0.470	0.0153
1000	0.461	0.448	0.0132	1000	0.470	0.457	0.0133	1000	0.492*	0.478	0.0136	1000	0.526*	0.511	0.0143
1100	0.502	0.489	0.0124	1100	0.513	0.500	0.0125	1100	0.534*	0.521	0.0128	1100	0.566*	0.553	0.0135
1200	0.549*	0.531	0.0118	1200	0.556*	0.544	0.0119	1200	0.578*	0.566	0.0122	1200	0.607*	0.594	0.0128

† Uncertainties of the total thermal conductivity, k, are as follows:
30.00 Cu - 70.00 Pd: ±15%.
25.00 Cu - 75.00 Pd: ±15%.
20.00 Cu - 80.00 Pd: ±15%.
15.00 Cu - 85.00 Pd: ±15%.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 14. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 10.00% (15.69 At.%) Pd: 90.00% (84.31 At.%)				Cu: 5.00% (8.10 At.%) Pd: 95.00% (91.90 At.%)				Cu: 3.00% (4.92 At.%) Pd: 97.00% (95.08 At.%)				Cu: 1.00% (1.66 At.%) Pd: 99.00% (98.34 At.%)			
ρ_o = 20.10 μΩcm				ρ_o = 10.31 μΩcm				ρ_o = 6.20 μΩcm				ρ_o = 2.100 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.00486		4		0.00948		4		0.0158		4		0.0465	
6		0.00729		6		0.0142		6		0.0236		6		0.0698	
8		0.00972		8		0.0190		8		0.0315		8		0.0931	
10		0.0122		10		0.0237		10		0.0394		10		0.116	
15		0.0182		15		0.0355		15		0.0591		15		0.175	
20		0.0243		20		0.0474		20		0.0788		20		0.233	
25		0.0304		25		0.0572		25		0.0959		25		0.276	
30		0.0365		30		0.0676		30		0.113		30		0.315	
40		0.0486		40		0.0871		40		0.143		40		0.364	
50		0.0602		50		0.105		50		0.167		50		0.382	
60		0.0680		60		0.120		60		0.214		60		0.389	
70		0.0756		70		0.135		70		0.230		70		0.397	
80		0.0848		80		0.149		80		0.246		80		0.407	
90		0.0940		90		0.162		90		0.261		90		0.417	
100		0.103		100		0.175		100		0.273		100		0.422	
150		0.141		150		0.223		150		0.294		150		0.441	
200	0.216*	0.175	0.0407	200	0.312*	0.261	0.0509	200		0.329		200		0.454	
250	0.241*	0.205	0.0360	250	0.337*	0.293	0.0448	250	0.411*	0.358	0.0533	250	0.547*	0.471	0.0762
273	0.252	0.218	0.0342	273	0.348	0.305	0.0426	273	0.421*	0.371	0.0505	273	0.553*	0.481	0.0719
300	0.266	0.234	0.0324	300	0.362	0.322	0.0403	300	0.435*	0.387	0.0477	300	0.562*	0.494	0.0676
350	0.292	0.262	0.0297	350	0.389	0.352	0.0367	350	0.462*	0.419	0.0434	350	0.585*	0.524	0.0606
400	0.317*	0.290	0.0274	400	0.415*	0.381	0.0339	400	0.486*	0.446	0.0399	400	0.605*	0.549	0.0554
500	0.366*	0.342	0.0240	500	0.465*	0.436	0.0295	500	0.533*	0.499	0.0346	500	0.646*	0.599	0.0471
600	0.412*	0.391	0.0215	600	0.515*	0.489	0.0263	600	0.579*	0.548	0.0307	600	0.690*	0.649	0.0411
700	0.456*	0.436	0.0196	700	0.559*	0.535	0.0239	700	0.623*	0.595	0.0277	700	0.731*	0.694	0.0365
800	0.499*	0.481	0.0180	800	0.661*	0.639	0.0219	800	0.665*	0.640	0.0253	800	0.770*	0.737	0.0329
900	0.541*	0.525	0.0168	900	0.641*	0.621	0.0202	900	0.706*	0.682	0.0233	900	0.808*	0.778	0.0299
1000	0.581*	0.566	0.0157	1000	0.676*	0.657	0.0189	1000	0.743*	0.722	0.0216	1000	0.847*	0.819	0.0275
1100	0.621*	0.606	0.0148	1100	0.711*	0.693	0.0177	1100	0.775*	0.755	0.0202	1100	0.886*	0.861	0.0254
1200	0.660*	0.646	0.0140	1200	0.745*	0.728	0.0167	1200	0.810*	0.791	0.0190	1200	0.926*	0.903	0.0236

† Uncertainties of the total thermal conductivity, k, are as follows:

10.00 Cu - 90.00 Pd: ±15%.
5.00 Cu - 95.00 Pd: ±15%.
3.00 Cu - 97.00 Pd: ±15%.
1.00 Cu - 99.00 Pd: ±15%.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 14. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 0.50% (0.83 At.%) Pd: 99.50% (99.17 At.%)						
ρ_0 = 1.100 $\mu\Omega$cm						
T	k	k_e	k_g			
4		0.0888				
6		0.133				
8		0.178				
10		0.222				
15		0.333				
20		0.444				
25		0.516				
30		0.557				
40		0.596				
50		0.582				
60		0.557				
70		0.539				
80		0.529				
90		0.530				
100		0.520				
150		0.504				
200		0.504				
250	0.606*	0.514	0.0922			
273	0.608*	0.521	0.0866			
300	0.615*	0.534	0.0809			
350	0.634*	0.562	0.0721			
400	0.652*	0.587	0.0650			
500	0.699*	0.634	0.0645			
600	0.730*	0.683	0.0469			
700	0.772*	0.731	0.0412			
800	0.810*	0.773	0.0367			
900	0.849*	0.816	0.0332			
1000	0.887*	0.857	0.0302			
1100	0.927*	0.899	0.0278			
1200	0.966*	0.940	0.0257			

† Uncertainties of the total thermal conductivity, k, are as follows:
0.50 Cu - 99.50 Pd: ±15%.

* In temperature range where no experimental thermal conductivity data are available.

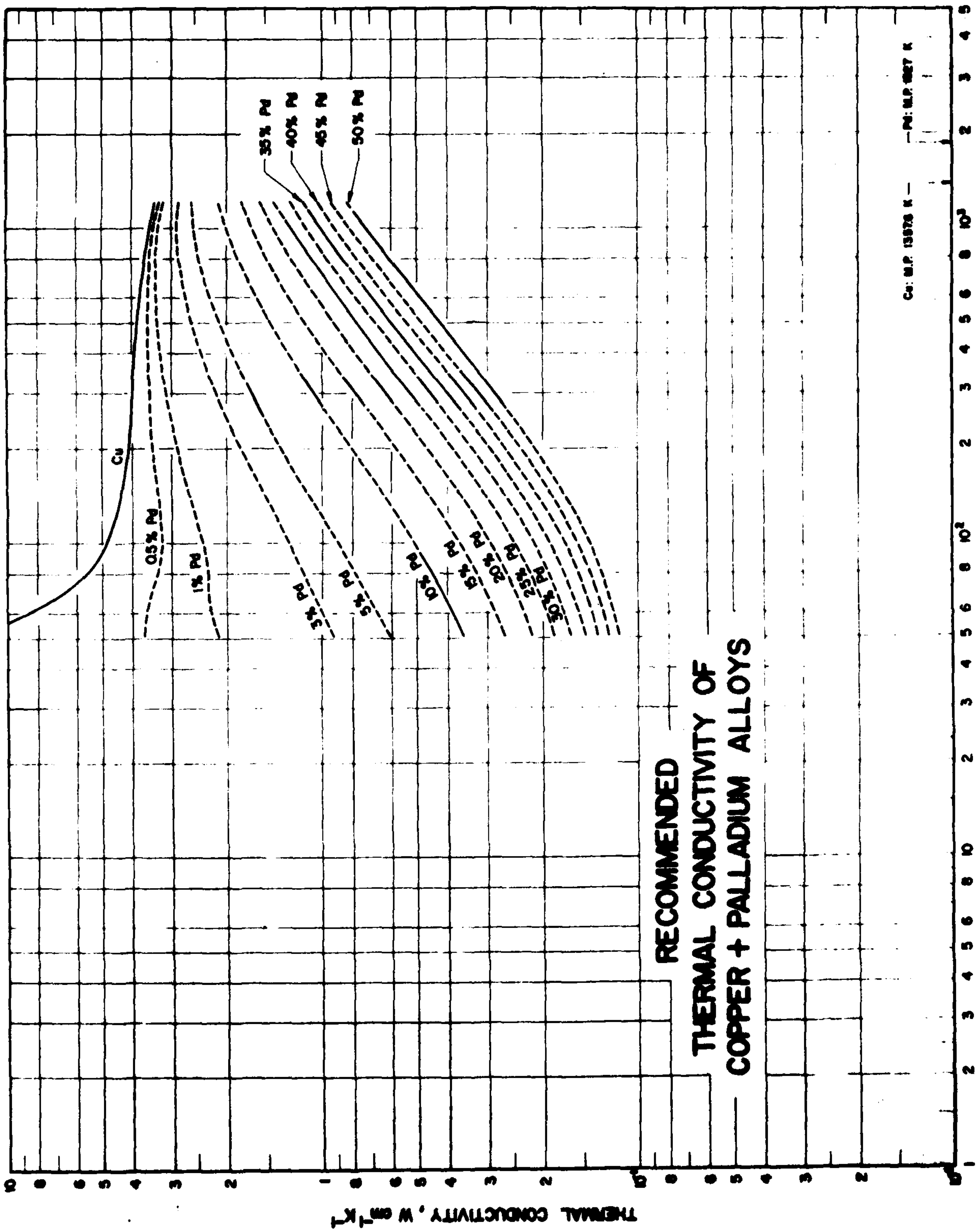
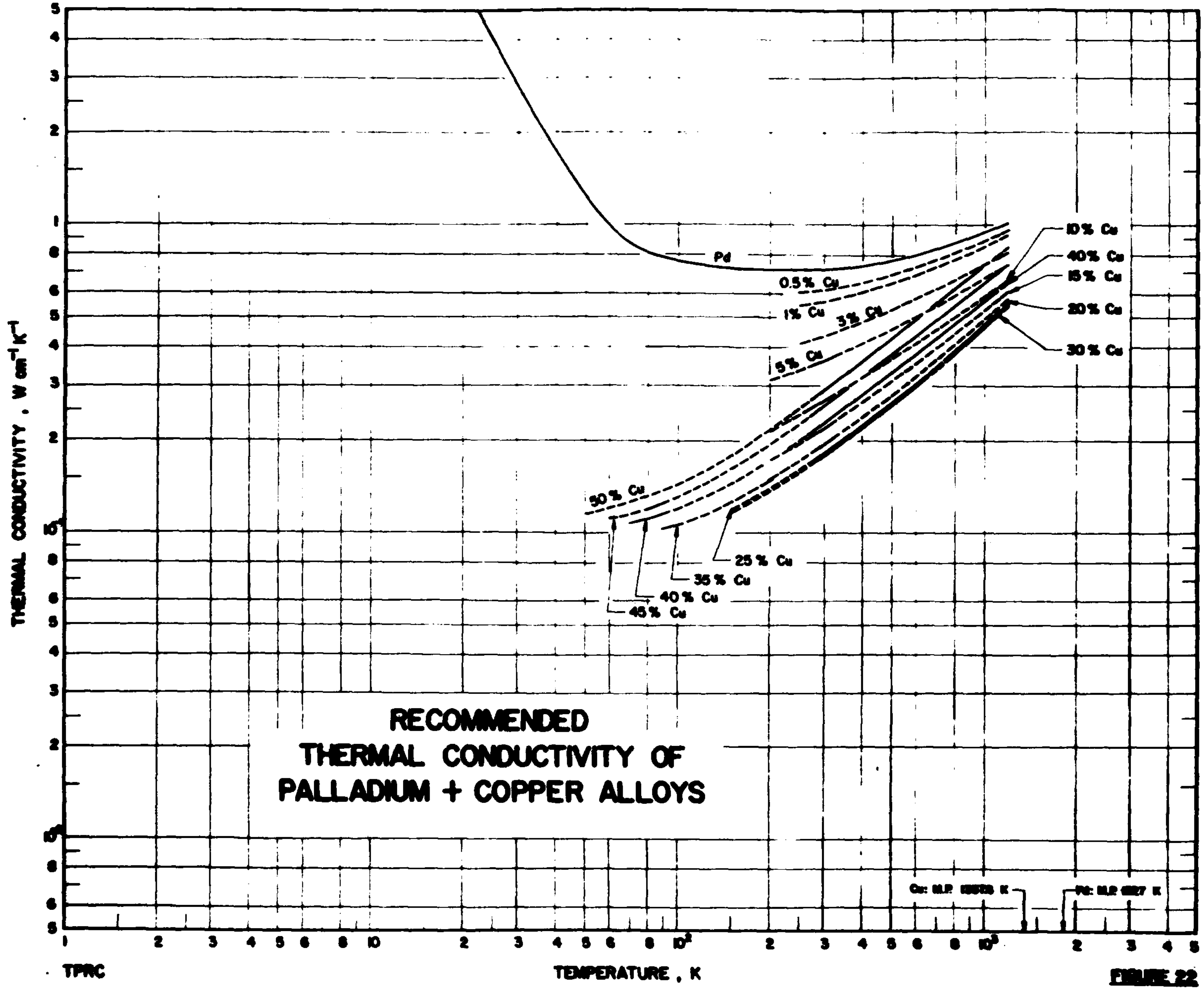
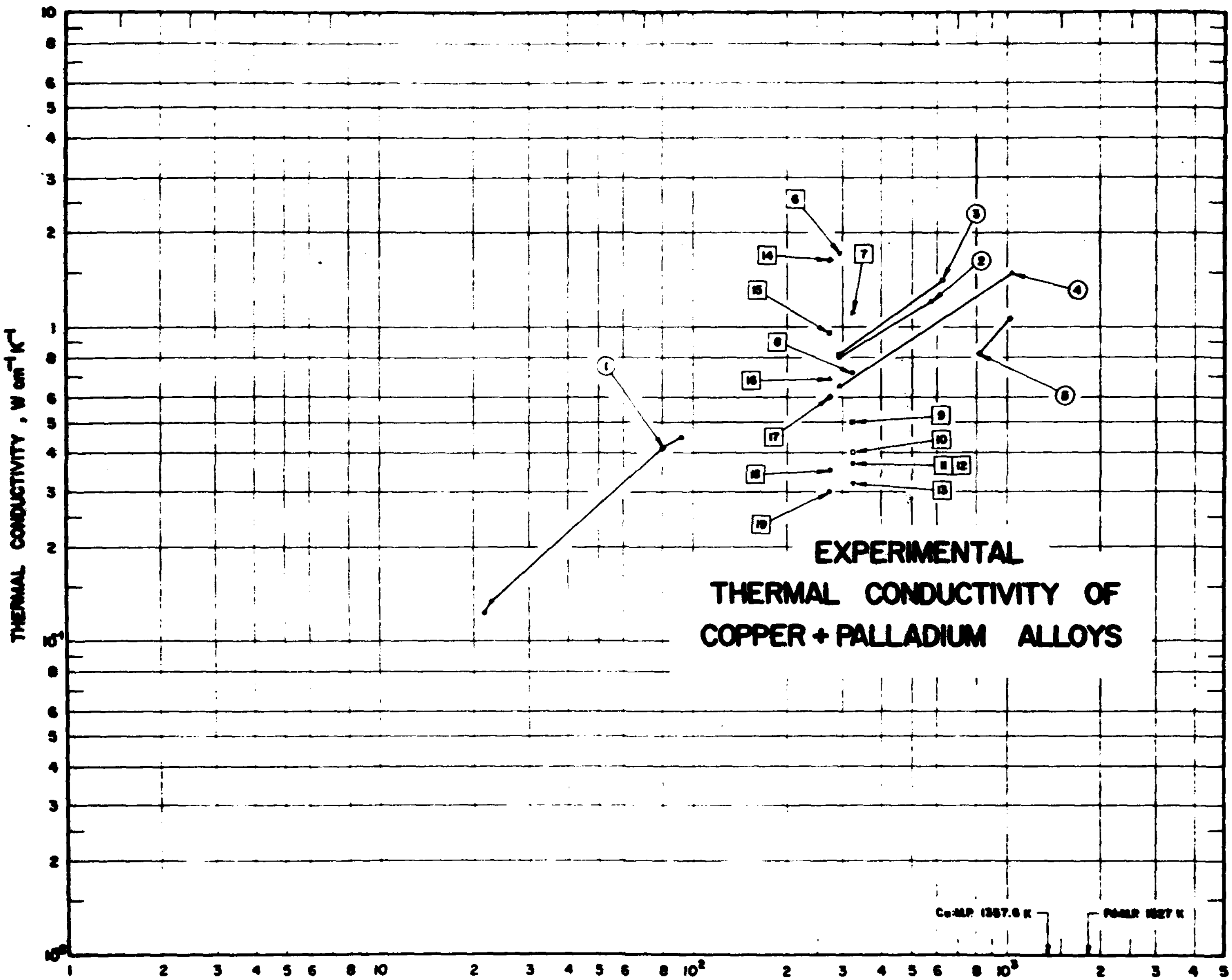

RECOMMENDED
THERMAL CONDUCTIVITY OF
COPPER + PALLADIUM ALLOYS
Cu
0.5% Pd
1% Pd
3% Pd
5% Pd
10% Pd
15% Pd
20% Pd
25% Pd
30% Pd
35% Pd
40% Pd
45% Pd
50% Pd
Cu: M.P. 1357.6 K
Pd: M.P. 1827 K
THERMAL CONDUCTIVITY, W cm^{-1} K^{-1}
TEMPERATURE, K
TPRC

FIGURE 21



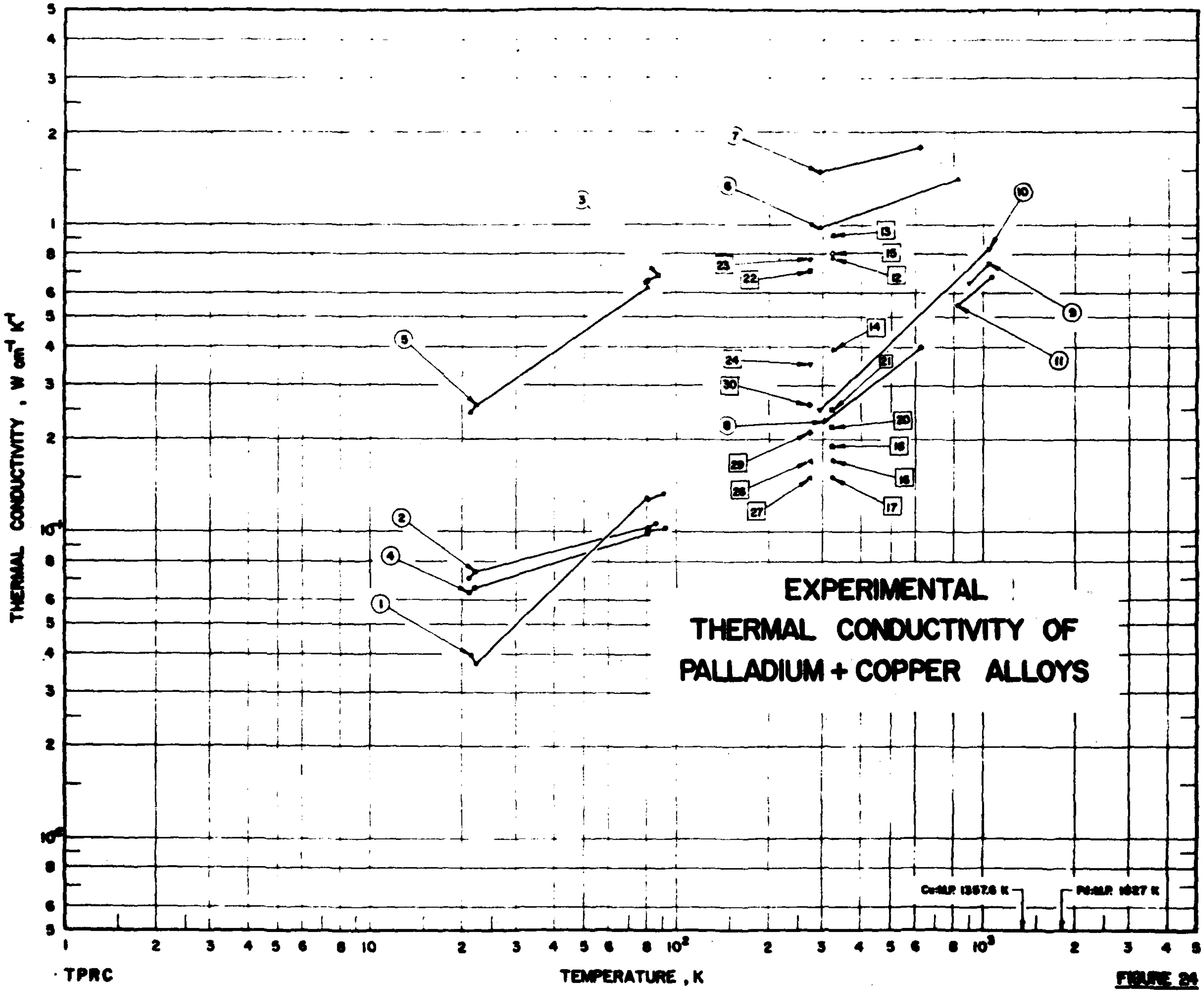
TPRC

FIGURE 22



TPRC

FIGURE 23



TPRC

FIGURE 24

TABLE 15. THERMAL CONDUCTIVITY OF COPPER + PALLADIUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Pd	Composition (continued), Specifications, and Remarks
1	61	Grüneisen, E. and Reddemann, H.	1934	L	22-91	20	89.7	10.3	Calculated composition; polycrystalline; electrical resistivity 6.82, 5.508, and 5.184 $\mu\Omega$ cm at 0, -190, and -251 C, respectively.
2	82	Pott, F.P.	1968	L	293, 573			24.18	Calculated composition; annealed at 600 to 700 C for 2 hr; ordered; electrical resistivity 9.7, 12.4, and 13.9 $\mu\Omega$ cm at 36, 300, and 480 C, respectively.
3	82	Pott, F.P.	1968	L	293, 623			35.82	Similar to the above specimen except electrical resistivity 10.5, 12.9, and 15.2 $\mu\Omega$ cm at 34, 251, and 449 C, respectively.
4	82	Pott, F.P.	1968	L	293, 1048			24.18	Similar to the above specimen except disordered with electrical resistivity 14.2, 17.1, and 19.3 $\mu\Omega$ cm at 19, 441, and 779 C, respectively.
5	82	Pott, F.P.	1968	L	818, 1028			35.82	Similar to the above specimen except electrical resistivity 19.7, 22.4, and 25.6 $\mu\Omega$ cm at 25, 400, and 800 C, respectively.
6	83	Kierspe, W.	1967	L	293.2			4.9	Cylindrical specimen; electrical resistivity 2.5862, 2.5865, 2.5901, 2.6052, 2.6379, 2.6849, 2.8092, 2.9047, 3.0440, 3.1847, 3.3258, 3.4636, 3.6005, 3.7351, 3.8703, 4.0055, 4.1351, and 4.2018 $\mu\Omega$ cm at 4.2, 10, 20, 30, 40, 50, 70, 83, 103, 123, 143, 163, 183, 203, 223, 243, 263, and 273 K, respectively.
7	178	Holgersson, S. and Sedström, E.	1924		323.2			8.41	Calculated composition (5.2 a/o Pd); electrical resistivity 6.8 $\mu\Omega$ cm at 50 C.
8	178	Holgersson, S. and Sedström, E.	1924		323.2			16.57	Calculated composition (10.6 a/o Pd); electrical resistivity 11.9 $\mu\Omega$ cm at 50 C.
9	178	Holgersson, S. and Sedström, E.	1924		323.2			22.40	Calculated composition (14.7 a/o Pd); electrical resistivity 15.4 $\mu\Omega$ cm at 50 C.
10	178	Holgersson, S. and Sedström, E.	1924		323.2			28.73	Calculated composition (19.4 a/o Pd); density 9.78 g cm^{-3}; electrical resistivity 18.8 $\mu\Omega$ cm at 50 C.
11	178	Holgersson, S. and Sedström, E.	1924		323.2			35.45	Calculated composition (24.7 a/o Pd); electrical resistivity 22.0 $\mu\Omega$ cm at 50 C.
12	178	Holgersson, S. and Sedström, E.	1924		323.2			42.36	Calculated composition (30.5 a/o Pd); electrical resistivity 27.0 $\mu\Omega$ cm at 50 C.
13	178	Holgersson, S. and Sedström, E.	1924		323.2			48.94	Calculated composition (36.4 a/o Pd); density 10.12 g cm^{-3}; electrical resistivity 29.8 $\mu\Omega$ cm at 50 C.
14	179	Sedström, E.	1924		273.2			3.5	Thermal conductivity value extracted from Schulze, A. (Z. Anorg. Chem., 159, 325-42, 1927).
15	179	Sedström, E.	1924		273.2			8.7	Same as above; electrical resistivity 6.90 $\mu\Omega$ cm at 0 C.
16	179	Sedström, E.	1924		273.2			11.1	Same data source as above.
17	179	Sedström, E.	1924		273.2			17.3	Same as above; electrical resistivity 11.79 $\mu\Omega$ cm at 0 C.
18	179	Sedström, E.	1924		273.2			42.8	Same as above; electrical resistivity 25.38 $\mu\Omega$ cm at 0 C.
19	179	Sedström, E.	1924		273.2			49.0	Same as above; electrical resistivity 29.67 $\mu\Omega$ cm at 0 C.

TABLE 16. THERMAL CONDUCTIVITY OF PALLADIUM + COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Cu	Composition (continued), Specifications, and Remarks
1	61	Grüneisen, E. and Reddemann, H.	1934	L	21-91	16	90.8	9.2	Calculated composition; polycrystalline; electrical resistivity 20.59, 22.18, and 28.05 $\mu\Omega$ cm at 22, 83, and 273 K, respectively.
2	61	Grüneisen, E. and Reddemann, H.	1934	L	21-85	19	62.7	37.3	Calculated composition; electrical resistivity 32.49, 33.68, 36.8, and 37.15 $\mu\Omega$ cm at 22, 83, 273, and 291.60 K, respectively.
3	61	Grüneisen, E. and Reddemann, H.	1934	L	79-87	21a	57.8	42.2	Calculated composition: electrical resistivity 3.168, 5.1, and 5.32 $\mu\Omega$ cm at 83, 273, and 292.6 K, respectively.
4	61	Grüneisen, E. and Reddemann, H.	1934	L	21-92	21b			The above specimen annealed in vacuo for 2 hr at ~850 C; electrical resistivity 33.47, 34.01, 36.4, and 36.6 $\mu\Omega$ cm at 22, 83, 273, and 291.60 K, respectively.
5	61	Grüneisen, E. and Reddemann, H.	1934	L	21-80	21c			The above specimen annealed at ~325 C for 30 hr; electrical resistivity 2.812, 3.286, and 5.25 $\mu\Omega$ cm at 22, 83, and 273 K, respectively.
6	82	Pott, F.P.	1958	L	293, 823		52.75	47.25	Calculated composition; specimen cut from a 0.2 mm thick sheet; cold-rolled, annealed for 2 hr at ~650 C; ordered atomic arrangement; electrical resistivity 7.8, 10.8, and 14.0 $\mu\Omega$ cm at 35, 300, and 590 C, respectively.
7	82	Pott, F.P.	1958	L	293, 623		57.81	42.19	Similar to the above specimen except electrical resistivity 4.3, 7.7, and 11.0 $\mu\Omega$ cm at 0, 291, and 560 C, respectively.
8	82	Pott, F.P.	1958	L	303, 623		70.67	29.33	Similar to the above specimen except electrical resistivity 49.3, 50.6, and 51.4 $\mu\Omega$ cm at 0, 314, and 580 C, respectively.
9	82	Pott, F.P.	1958	L	893, 1048		52.75	47.25	Similar to the above specimen except disordered atomic arrangement and electrical resistivity 28.4, 31.4, and 35.9 $\mu\Omega$ cm at 25, 400, and 792 C, respectively.
10	82	Pott, F.P.	1958	L	293, 1048		57.81	42.19	Similar to the above specimen except electrical resistivity 34.2, 37.4, and 41.4 $\mu\Omega$ cm at 36, 400, and 800 C, respectively.
11	82	Pott, F.P.	1958	L	821, 1073		70.67	29.33	Similar to the above specimen except electrical resistivity 47.6, 49.7, and 51.7 $\mu\Omega$ cm at 32, 400, and 800 C, respectively.
12	178	Holgersson, S. and Sedström, E.	1924		323.2			48.40	Calculated composition (61.1 a/o Cu); electrical resistivity 11.9 $\mu\Omega$ cm at 50 C.
13	178	Holgersson, S. and Sedström, E.	1924		323.2			47.56	Calculated composition (60.3 a/o Cu); electrical resistivity 10.3 $\mu\Omega$ cm at 50 C.
14	178	Holgersson, S. and Sedström, E.	1924		323.2			41.70	Calculated composition (54.5 a/o Cu); density 10.35 g cm^{-3}; electrical resistivity 19.1 $\mu\Omega$ cm at 50 C.
15	178	Holgersson, S. and Sedström, E.	1924		323.2			37.58	Calculated composition (49.8 a/o Cu); electrical resistivity 10.0 $\mu\Omega$ cm at 50 C.
16	178	Holgersson, S. and Sedström, E.	1924		323.2			35.63	Calculated composition (48.1 a/o Cu); density 10.50 g cm^{-3}; electrical resistivity 48.1 $\mu\Omega$ cm at 50 C.
17	178	Holgersson, S. and Sedström, E.	1924		323.2			33.36	Calculated composition (45.6 a/o Cu); density 10.96 g cm^{-3}; electrical resistivity 50.1 $\mu\Omega$ cm at 50 C.
18	178	Holgersson, S. and Sedström, E.	1924		323.2			28.99	Calculated composition (40.6 a/o Cu); electrical resistivity 55.4 $\mu\Omega$ cm at 50 C.

TABLE 16. THERMAL CONDUCTIVITY OF PALLADIUM + COPPER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Cu	Composition (continued), Specifications, and Remarks
19	178	Holgersson, S. and Sedström, E.	1924		323.2			20.22	Calculated composition (29.8 a/o Cu); density 11.26 g cm^{-3}; electrical resistivity 51.4 $\mu\Omega$ cm at 50 C.
20	178	Holgersson, S. and Sedström, E.	1924		323.2			14.13	Calculated composition (21.6 a/o Cu); electrical resistivity 41.1 $\mu\Omega$ cm at 50 C.
21	178	Holgersson, S. and Sedström, E.	1924		323.2			6.81	Calculated composition (10.9 a/o Cu); electrical resistivity 29.7 $\mu\Omega$ cm at 50 C.
22	179	Sedström, E.	1924		273.2		51.6		Thermal conductivity value extracted from Schulze, A. (Z. Anorg. Chem., 159, 325–42, 1927); electrical resistivity 11.10 $\mu\Omega$ cm at 0 C.
23	179	Sedström, E.	1924		273.2		52.5		Same as above but electrical resistivity 8.77 $\mu\Omega$ cm at 0 C.
24	179	Sedström, E.	1924		273.2		58.4		Same as above but electrical resistivity 18.28 $\mu\Omega$ cm at 0 C.
25	179	Sedström, E.	1924		273.2		62.4		Same as above but electrical resistivity 8.26 $\mu\Omega$ cm at 0 C.
26	179	Sedström, E.	1924		273.2		64.4		Same as above but electrical resistivity 47.39 $\mu\Omega$ cm at 0 C.
27	179	Sedström, E.	1924		273.2		66.7		Same data source as above.
28	179	Sedström, E.	1924		273.2		79.8		Same as above; electrical resistivity 50.76 $\mu\Omega$ cm at 0 C.
29	179	Sedström, E.	1924		273.2		85.9		Same as above but electrical resistivity 40.16 $\mu\Omega$ cm at 0 C.
30	179	Sedström, E.	1924		273.2		93.0		Same as above but electrical resistivity 27.32 $\mu\Omega$ cm at 0 C.

4.6. Copper-Zinc Alloy System

The copper-zinc alloy system does not constitute a continuous series of solid solutions. The maximum solid solubility of zinc in copper is 38.3% (39.0 At.%) at 727 K and the solubility decreases at higher and lower temperatures. At lower temperatures, the attainment of equilibrium becomes very slow and the solubility data are uncertain. Massalski and Kittl [86] have analyzed existing data and have concluded that the boundary lies at about 35% Zn at 473 K and suggest that it may lie at less than 30% Zn at room temperature. Shinoda and Amano [87] have reported a much greater reduction in solubility at room temperature.

There are 91 sets of experimental data available for the thermal conductivity of Cu + Zn alloys as listed in Table 18 and shown in Figure 26. Of these, seven sets are merely single data points, 24 sets cover a narrow temperature range from around room temperature to about 500 K, and 17 sets are for temperatures below 4.5 K. Most of the measurements were on alloys in the solid solution region. Surprisingly there are no data available for the Zn + Cu alloys on either the thermal conductivity or the electrical resistivity. Consequently, only Cu + Zn alloys are treated in the present work.

In order to ascertain the reliability of experimental data and to fill gaps in data, the lattice and electronic components of the thermal conductivity of the Cu + Zn alloys were calculated. The electronic component was calculated from eq. (12). However, these calculations were limited to temperatures below 400 K, since no reliable electrical resistivity data were available at higher temperatures. Where values of the electronic component are reported at higher temperatures in Table 17, these were obtained by graphical smoothing of the differences between the experimental thermal conductivity data and the calculated values of the lattice thermal conductivity. Estimates of the lattice thermal conductivity in the low temperature region were based on experimental data and values in the high temperature region were calculated from eq. (35). In the intermediate range, near the maximum, graphical techniques were used to smoothly join the high and low temperature values (following a crude separation of k_g as a guide). The high temperature calculations of the lattice component were limited to alloys with Zn not exceeding 30%.

The low temperature lattice thermal conductivity of solid-solution Cu + Zn alloys in both strained and annealed states has been extensively investigated by Kemp, et al. [62, 88, 89] (curves 17-24 and 27-33). Their results show that the lattice and total thermal conductivities of the alloys increase markedly as the annealing temperature is increased, due to the removal of both point defects and dislocations. This increase is illustrated by curves 30-33 in Figure 26 for an alloy with 32% Zn. Apparently the dislocations are locked in by the impurity atoms, and cannot be removed by normal annealing just above the recrystallization temperature. Even annealing the alloys at temperatures near the melting point was found to remove only a fraction of the dislocations. In recommending low-temperature

lattice thermal conductivities, only the data for alloys annealed at high temperatures were used. The values given in Table 17 were based primarily on the data of Kemp, et al. [62] for alloys with 2.06, 5.14, and 10.26% Zn (curves 27-29), which were annealed at 1123 K. Because the low temperature lattice thermal conductivities of solid-solution Cu + Zn alloys do not vary greatly with composition in the 10-30% Zn range, it was possible to estimate the lattice components of alloys in this range by graphically extending the conductivity-composition curves formed by the 2.06, 5.14, and 10.26% Zn alloys to higher Zn concentrations, using data of Kemp, et al. [88] for alloys annealed at a lower temperature (773 K) (curves 18, 20, and 24) as a guide. Although this procedure should not introduce unacceptable uncertainties, the lattice components reported for the 10-30% Zn alloys should be accepted with more caution than those for which direct, supporting experimental data are available.

Problems were encountered in attempts to develop reliable estimates of the lattice thermal conductivities of the alloys at high temperatures. Initially, the lattice components for the alloys were calculated by using White and Woods' [90, 91] value of 35.0 watts cm^{-1} for the value of $k_g T$ of pure copper to determine $k_u(T')$ in eq. (35). However, calculations of the lattice components from high temperature measurements by Kemp, et al. [62, 88, 89] (curves 17-24 and 27-33) and Smith [92] (curves 1-13) of the total thermal conductivity and the electrical resistivity for the same alloy samples were as much as 50% higher than the values calculated using eq. (35) with White and Woods' values for the lattice component of copper. It was found that this discrepancy could be reduced by increasing the values for the lattice component of pure copper by 50% at high temperatures. This resulted in a much better agreement between experimental and calculated values of the lattice component over the entire range of compositions. However, because of this conflict between White and Woods' value for the lattice component of copper and the available experimental data for copper-zinc alloys, the lattice components of the dilute copper-zinc alloys are not reported at high temperatures.

The recommended total thermal conductivity values are in agreement with the data at low temperatures of Lomer [161] (curves 80-86), Kemp, et al. [88] (curves 18, 20-22, and 24), Kemp, et al. [89] (curve 33), and Olsen [157] (curves 56-59) to within 10%, and with the data at higher temperatures of Smith [92] (curves 1-8, 11, 71, and 72), Smith and Palmer [49] (curve 14), Bailey [151] (curve 15), and Lees [152] (curve 16) to within 8%.

The recommended values for k, k_e, and k_g are tabulated in Table 17 for nine alloy compositions ranging from 0.50 to 30% Zn. These values are for well-annealed alloys. The values for k are also shown in Figure 25, covering the temperature range from 4 to 700 K. The values of residual electrical resistivity for the alloys are also given in Table 17. The uncertainties of the k values are stated in a footnote to Table 17, while the uncertainties of the k_e and k_g values are indicated by their being designated as recommended or provisional

values. The ranges of uncertainties of recommended and provisional values are less than ±15% and between ±15% and ±30%, respectively.

TABLE 17. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-ZINC ALLOY SYSTEM†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 99.50% (99.51 At.%) Zn: 0.50% (0.49 At.%) ρ_0 = 0.1500 μΩcm				Cu: 99.00% (99.03 At.%) Zn: 1.00% (0.97 At.%) ρ_0 = 0.2650 μΩcm				Cu: 97.00% (97.08 At.%) Zn: 3.00% (2.92 At.%) ρ_0 = 0.705 μΩcm				Cu: 95.00% (95.13 At.%) Zn: 5.00% (4.87 At.%) ρ_0 = 1.090 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.675*	0.651	0.0235‡	4	0.389	0.369	0.0196‡	4	0.152	0.139	0.0129	4	0.101	0.0897	0.0114
6	1.03*	0.977	0.0565‡	6	0.603	0.553	0.0498‡	6	0.242	0.208	0.0341	6	0.162	0.134	0.0280
8	1.40*	1.30	0.104‡	8	0.834	0.738	0.0960‡	8	0.345	0.277	0.0677	8	0.232	0.179	0.0530
10	1.79*	1.63	0.160‡	10	1.07	0.922	0.148‡	10	0.453	0.347	0.106	10	0.309	0.224	0.0850
15	2.73*	2.44	0.290‡	15	1.64	1.38	0.264‡	15	0.705	0.520	0.185	15	0.496	0.336	0.160
20	3.65*	3.26	0.385‡	20	2.19	1.84	0.346‡	20	0.945	0.693	0.252	20	0.667	0.448	0.219
25	4.24*	3.79	0.447‡	25	2.61	2.21	0.399‡	25	1.15	0.853	0.298‡	25	0.808	0.547	0.261‡
30	4.80*	4.31	0.489‡	30	3.00	2.57	0.434‡	30	1.33	1.00	0.331‡	30	0.935	0.645	0.290‡
40	5.30*	4.77	0.533‡	40	3.48	3.01	0.468‡	40	1.64	1.27	0.366‡	40	1.14	0.823	0.320‡
50	5.10*			50	3.61			50	1.82			50	1.30	0.968	0.327‡
60	4.61*			60	3.52			60	1.89			60	1.39	1.07	0.320‡
70	4.36*			70	3.34			70	1.95			70	1.46	1.15	0.308‡
80	4.08*			80	3.24			80	1.99			80	1.51	1.22	0.295‡
90	3.92*			90	3.22			90	2.05			90	1.58	1.29	0.284‡
100	3.86*			100	3.21			100	2.11			100	1.64	1.37	0.274‡
150	3.81*			150	3.34			150	2.42			150	1.95	1.72	0.230‡
200	3.79*			200	3.47*			200	2.65			200	2.18	1.98	0.198‡
250	3.77*			250	3.50*			250	2.80			250	2.36		
273	3.76*			273	3.52			273	2.85			273	2.41		
300	3.76			300	3.54			300	2.90			300	2.49		
350	3.75			350	3.56			350	2.97			350	2.58		
400	3.74			400	3.57			400	3.03			400	2.65		
500	3.70			500	3.57			500	3.11			500	2.77		
600	3.67*			600	3.57*			600	3.18*			600	2.89*		
700	3.63*			700	3.57*			700	3.26*			700	2.99*		
800				800				800				800			
900				900				900				900			
1000				1000				1000				1000			
1100				1100				1100				1100			
1200				1200				1200				1200			

† Uncertainties of the total thermal conductivity, k, are as follows:

99.50 Cu - 0.50 Zn: ±10%.
99.00 Cu - 1.00 Zn: ±10%.
97.00 Cu - 3.00 Zn: ±10%.
95.00 Cu - 5.00 Zn: ±10% below 300 K and ±5% above 300 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 17. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-ZINC ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 90.00% (90.25 At.%) Zn: 10.00% (9.75 At.%)				Cu: 85.00% (85.36 At.%) Zn: 15.00% (14.64 At.%)				Cu: 80.00% (80.45 At.%) Zn: 20.00% (19.55 At.%)				Cu: 75.00% (75.53 At.%) Zn: 25.00% (24.47 At.%)			
ρ_0 = 1.840 μΩcm				ρ_0 = 2.360 μΩcm				ρ_0 = 2.840 μΩcm				ρ_0 = 3.200 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0640	0.0531	0.0109	4	0.0519	0.0411	0.0108‡	4	0.0448	0.0344	0.0104‡	4	0.0408	0.0305	0.0103‡
6	0.105	0.0797	0.0254	6	0.0865*	0.0616	0.0249‡	6	0.0759	0.0516	0.0243‡	6	0.0646	0.0458	0.0238‡
8	0.152	0.106	0.0461	8	0.137*	0.0821	0.0448‡	8	0.113	0.0688	0.0441‡	8	0.104	0.0611	0.0433‡
10	0.204	0.133	0.0708	10	0.172*	0.103	0.0694‡	10	0.154	0.0860	0.0680‡	10	0.144	0.0763	0.0672‡
15	0.332	0.199	0.133	15	0.281*	0.154	0.127‡	15	0.254	0.129	0.125‡	15	0.237	0.115	0.122‡
20	0.450	0.266	0.184	20	0.378*	0.205	0.173‡	20	0.338	0.172	0.166‡	20	0.313	0.153	0.160‡
25	0.545	0.326	0.220	25	0.455*	0.252	0.203‡	25	0.402	0.212	0.190‡	25	0.373	0.189	0.184‡
30	0.631	0.388	0.243	30	0.520*	0.299	0.221‡	30	0.459	0.253	0.206‡	30	0.422	0.225	0.197‡
40	0.762	0.503	0.259‡	40	0.623*	0.389	0.234‡	40	0.546	0.329	0.217‡	40	0.497	0.292	0.205‡
50	0.861	0.601	0.260‡	50	0.699*	0.466	0.233‡	50	0.611	0.396	0.215‡	50	0.556	0.353	0.203‡
60	0.938	0.682	0.256‡	60	0.761*	0.534	0.227‡	60	0.660	0.452	0.208‡	60	0.601	0.406	0.196‡
70	0.994	0.748	0.246‡	70	0.811*	0.592	0.219‡	70	0.703	0.503	0.200‡	70	0.638	0.450	0.188‡
80	1.05	0.810	0.239‡	80	0.854	0.644	0.210‡	80	0.742	0.550	0.192‡	80	0.673	0.493	0.180‡
90	1.10	0.869	0.231‡	90	0.898	0.697	0.201‡	90	0.780	0.596	0.184‡	90	0.707	0.535	0.172‡
100	1.15	0.934	0.219‡	100	0.943	0.751	0.192‡	100	0.818	0.643	0.176‡	100	0.742	0.578	0.164‡
150	1.41	1.23	0.183‡	150	1.16	1.00	0.160‡	150	1.01	0.867	0.146‡	150	0.918	0.782	0.136‡
200	1.62	1.47	0.158‡	200	1.35	1.21	0.138‡	200	1.18	1.05	0.126‡	200	1.07	0.951	0.118‡
250	1.79	1.65	0.140‡	250	1.50	1.38	0.122‡	250	1.32	1.20	0.111‡	250	1.20	1.09	0.104‡
273	1.86	1.72	0.135‡	273	1.56	1.44	0.116‡	273	1.37	1.26	0.106‡	273	1.24	1.15	0.0992‡
300	1.93	1.80	0.128‡	300	1.62	1.51	0.110‡	300	1.43	1.33	0.100‡	300	1.30	1.20	0.0940‡
350	2.03	1.92	0.114‡	350	1.73	1.63	0.100‡	350	1.52	1.43	0.0918‡	350	1.39	1.30	0.0859‡
400	2.12	2.02	0.105‡	400	1.81	1.72	0.0925‡	400	1.60	1.51	0.0847‡	400	1.46	1.38	0.0793‡
500	2.29	2.20	0.0910‡	500	1.96	1.88	0.0805‡	500	1.73	1.66	0.0738‡	500	1.59	1.52	0.0692‡
600	2.41*	2.33	0.0806‡	600	2.09*	2.02	0.0716‡	600	1.86*	1.79	0.0657‡	600	1.70	1.64	0.0617‡
700	2.51*	2.44	0.0726‡	700	2.20*	2.14	0.0646‡	700	1.96*	1.90	0.0595‡	700	1.78	1.72	0.0559‡
800				800				800				800			
900				900				900				900			
1000				1000				1000				1000			
1100				1100				1100				1100			
1200				1200				1200				1200			

† Uncertainties of the total thermal conductivity, k, are as follows:
90.00 Cu - 10.00 Zn: ±10% below 300 K and ±5% above 300 K.
85.00 Cu - 15.00 Zn: ±10% below 300 K and ±5% above 300 K.
80.00 Cu - 20.00 Zn: ±15% below 70 K and ±10% above 70 K.
75.00 Cu - 25.00 Zn: ±15% below 70 K and ±10% above 70 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 17. RECOMMENDED THERMAL CONDUCTIVITY OF COPPER-ZINC ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Cu: 70.00% (70.59 At.%) Zn: 30.00% (29.41 At.%)						
ρ_0 = 3.390 μΩcm						
T	k	k_e	k_g			
4	0.0389	0.0288	0.0101‡			
6	0.0667	0.0432	0.0235‡			
8	0.0998	0.0577	0.0421‡			
10	0.148	0.0721	0.0759‡			
15	0.227	0.108	0.119‡			
20	0.300	0.144	0.156‡			
25	0.356	0.178	0.178‡			
30	0.400	0.211	0.189‡			
40	0.472	0.275	0.197‡			
50	0.526	0.331	0.196‡			
60	0.565	0.378	0.186‡			
70	0.601	0.421	0.180‡			
80	0.635	0.462	0.173‡			
90	0.664	0.500	0.164‡			
100	0.697	0.541	0.156‡			
150	0.863	0.733	0.130‡			
200	1.00	0.892	0.112‡			
250	1.12	1.03	0.0901‡			
273	1.17	1.08	0.0943‡			
300	1.22	1.13	0.0884‡			
350	1.30	1.22	0.0817‡			
400	1.37	1.29	0.0755‡			
500	1.49	1.42	0.0659‡			
600	1.59	1.53	0.0586‡			
700	1.66	1.61	0.0524‡			
800						
900						
1000						
1100						
1200						

† Uncertainties of the total thermal conductivity, k, are as follows:
70.00 Cu - 30.00 Zn: ±15% below 70 K and ±10% above 70 K.

‡ Provisional value.

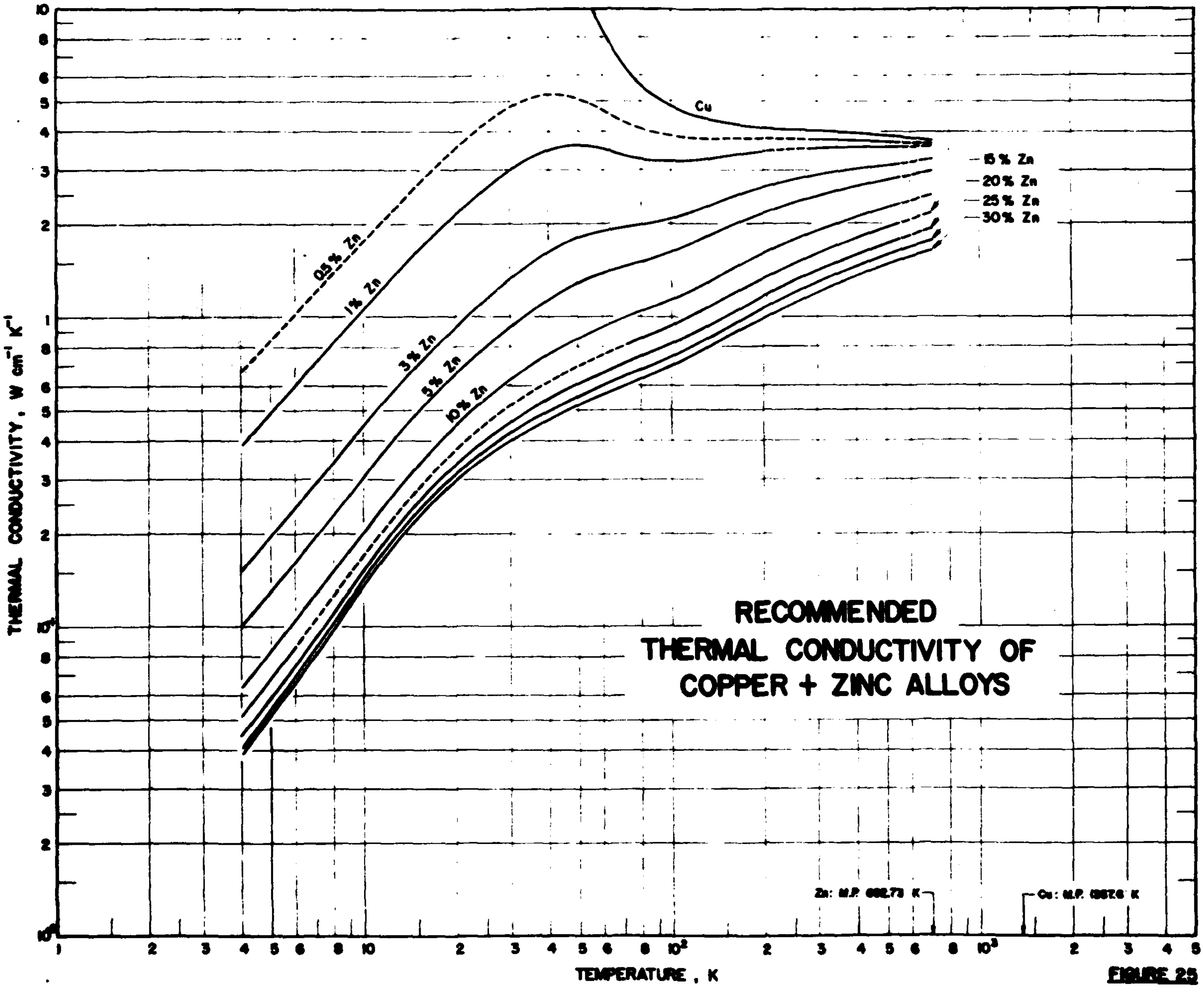

RECOMMENDED
THERMAL CONDUCTIVITY OF
COPPER + ZINC ALLOYS
THERMAL CONDUCTIVITY, W cm⁻¹ K⁻¹
TEMPERATURE, K
Cu
0.5% Zn
1% Zn
3% Zn
5% Zn
10% Zn
15% Zn
20% Zn
25% Zn
30% Zn
Zn: M.P. 692.73 K
Cu: M.P. 1357.6 K

FIGURE 25

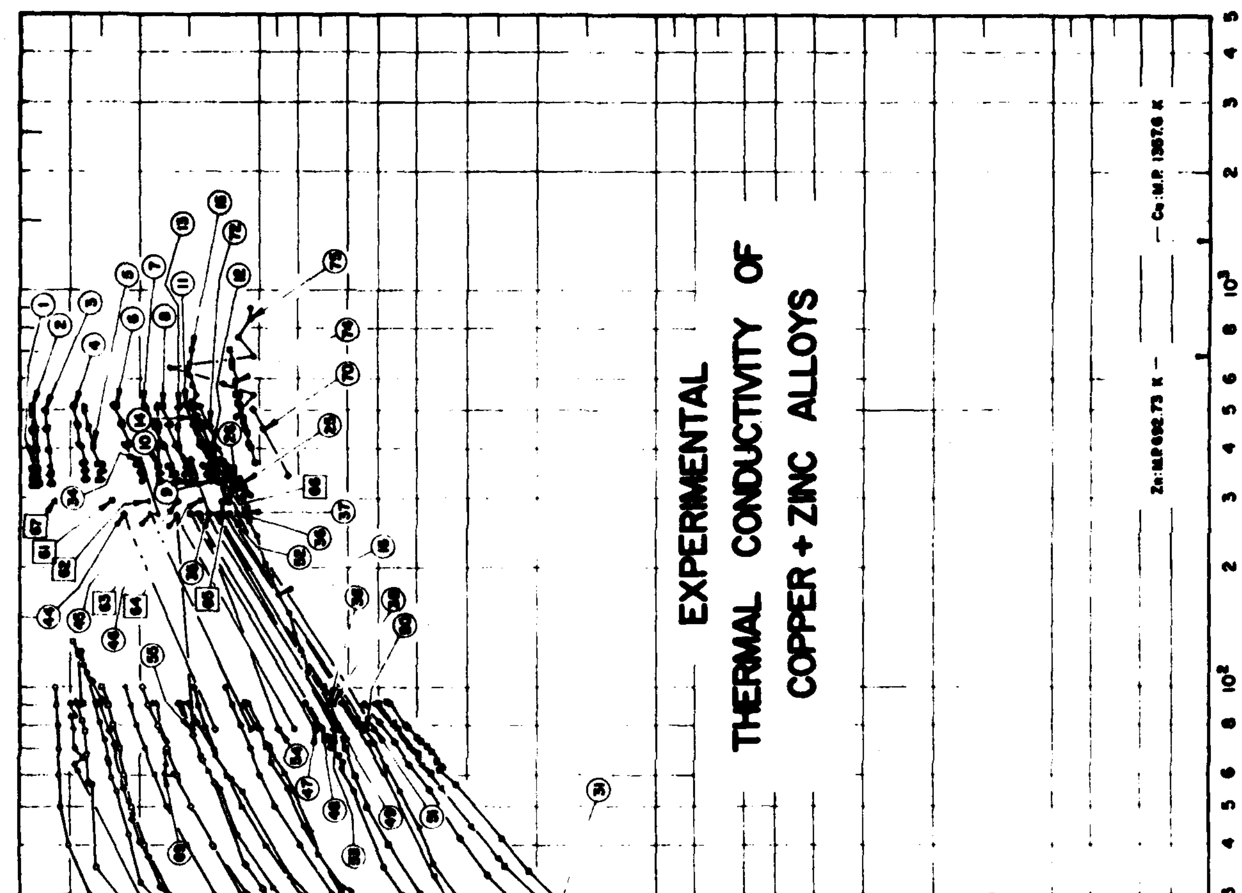

EXPERIMENTAL
THERMAL CONDUCTIVITY OF
COPPER + ZINC ALLOYS
Zn: M.P. 692.73 K
Cu: M.P. 1357.6 K
TEMPERATURE , K
THERMAL CONDUCTIVITY , W cm⁻¹ K⁻¹
TPRC

FIGURE 26

TABLE 18. THERMAL CONDUCTIVITY OF COPPER - ZINC ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
1	92	Smith, C.S.	1930	L	319-494	90	99.64	0.35	0.02 Fe and 0.01 Pb; polycrystalline; cylindrical specimen 13.25 in. long and 0.750 in. diameter; grain size 0.070 mm; annealed at 650 C for 1 hr, cooled in air; electrical conductivity 55.264 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
2	92	Smith, C.S.	1930	L	323-501	89	99.45	0.51	0.01 Fe and 0.01 Pb; similar to the above specimen except grain size 0.110 mm and electrical conductivity 53.325 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
3	92	Smith, C.S.	1930	L	324-494	73	98.93	0.95	0.02 Fe; similar to the above specimen except annealing temperature 700 C and grain size 0.120 mm; electrical conductivity 47.686 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
4	49, 92	Smith, C.S.	1930	L	332-506	12	96.94	3.04	0.02 Fe; similar to the above specimen except annealing time 0.75 hr, grain size 0.100 mm, and electrical conductivity 36.607 and 25.21 x $10^4 \Omega^{-1} cm^{-1}$ at 20 and 200 C, respectively.
5	49, 92	Smith, C.S.	1930	L	328-507	13	95.21	4.77	Similar to the above specimen except grain size 0.085 mm and electrical conductivity 33.062 and 23.31 x $10^4 \Omega^{-1} cm^{-1}$ at 20 and 200 C, respectively.
6	92	Smith, C.S.	1930	L	328-510	14	90.07	9.91	0.01 Fe and 0.01 Pb; similar to the above specimen but grain size 1 mm and electrical conductivity 25.293 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
7	92	Smith, C.S.	1930	L	326-504	15	83.20	16.76	0.03 Fe and 0.01 Pb; similar to the above specimen except grain size 0.125 mm and electrical conductivity 20.108 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
8	92	Smith, C.S.	1930	L	327-510	16	79.62	20.35	0.01 Fe and 0.02 Pb; similar to the above specimen except grain size 0.190 mm and electrical conductivity 18.459 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
9	92	Smith, C.S.	1930	L	325-512	22	59.20	40.75	0.02 Fe and 0.03 Pb; same structure and dimensions as the above specimen; grain size 0.070 mm; annealed at 650 C for 3 hr; cooled in furnace; electrical conductivity 16.700 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
10	92	Smith, C.S.	1930	L	328-508	85	50.30	49.49	0.01 Fe and 0.04 Pb; similar to the above specimen but annealing time 2 hr, grain size 16 mm, and electrical conductivity 23.812 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
11	92	Smith, C.S.	1930	L	329-512	18	69.14	30.81	0.03 Fe and 0.02 Pb; same structure and dimensions as the above specimen; annealed at 650 C for 0.75 hr, cooled in air; electrical conductivity 15.857 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
12	92	Smith, C.S.	1930	L	329-511	21	65.43	34.53	0.01 Fe and 0.03 Pb; similar to the above specimen except grain size 0.080 mm and electrical conductivity 15.325 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
13	92	Smith, C.S.	1930	L	326-505	88	54.96	45.02	0.01 Fe; similar to the above specimen except annealing time 2 hr, grain size 0.040 mm, and electrical conductivity 20.466 x $10^4 \Omega^{-1} cm^{-1}$ at 20 C.
14	49	Smith, C.S. and Palmer, E.W.	1935	L	293, 473	19	66.24	33.72	0.03 Pb and 0.01 Fe; annealed at 650 C for 0.75 hr; electrical conductivity 15.63 and 12.24 x $10^4 \Omega^{-1} cm^{-1}$ at 20 and 200 C, respectively.
15	151	Bailey, L.C.	1931	L	351-703	Brass 70/30	70	30	7 to 8 cm long and 0.585 cm in diameter; density 8.44 g cm^{-3} at 22 C.
16	152	Lees, C.H.	1908	L	108-299	Brass 70/30	70	30	7 to 8 cm long and 0.585 cm in diameter; density 8.44 g cm^{-3} at 22 C.
17	88	Kemp, W.R.G., Klemens, P.G., Tainsh, R.J., and White, G.K.	1957	L	2.8-123	2S		1.63	~8 cm long and 0.5 cm in diameter; supplied by Johnson Matthey and Co., Ltd.; as drawn; residual electrical resistivity 0.425 $\mu\Omega$ cm.

TABLE 18. THERMAL CONDUCTIVITY OF COPPER + ZINC ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
18	88	Kemp, W.R.G., Klemens, P.G., Tainsh, R.J., and White, G.K.	1957	L	2.0-130	2			The above specimen annealed at 500 C for 4 hr in helium atmosphere; residual electrical resistivity 0.38 μΩ cm.
19	88	Kemp, W.R.G., et al.	1957	L	2.1-91	5S		5.37	Same dimensions and supplier as the above specimen; as drawn; residual electrical resistivity 1.22 μΩ cm.
20	88	Kemp, W.R.G., et al.	1957	L	2.5-91	5			The above specimen annealed at 500 C for 4 hr in a helium atmosphere; residual electrical resistivity 1.12 μΩ cm.
21	88	Kemp, W.R.G., et al.	1957	L	1.9-91	10		9.98	Similar to the above specimen except residual electrical resistivity 1.88 μΩ cm.
22	88	Kemp, W.R.G., et al.	1957	L	1.9-91	20		19.48	Similar to the above specimen except residual electrical resistivity 2.97 μΩ cm.
23	88	Kemp, W.R.G., et al.	1957	L	2.5-91	30S		31.87	Same dimensions and supplier as the above specimen; as drawn; residual electrical resistivity 4.31 μΩ cm.
24	88	Kemp, W.R.G., et al.	1957	L	2.2-91	30			The above specimen annealed in a helium atmosphere at 500 C for 4 hr; residual electrical resistivity 3.60 μΩ cm.
25	153	Raeth, C.H.	1944	L	302-335	Brass			Cylindrical specimen 2.565 cm long and 5.017 cm² in cross-sectional area.
26	153	Raeth, C.H.	1944	L	314-344	Brass			Cylindrical specimen 2.570 cm long and 3.447 cm² in cross-sectional area.
27	62	Kemp, W.R.G., Klemens, P.G., and Tainsh, R.J.	1957	L	1.9-121			2.06	8 cm long and 0.5 cm in diameter; drawn; annealed at 850 C for 4 hr; electrical resistivity reported as 0.563, 0.873, and 2.273 μΩ cm at 0, 90, and 293 K, respectively.
28	62	Kemp, W.R.G., et al.	1957	L	2.0-91			5.14	Similar to the above specimen except electrical resistivity reported as 1.20, 1.53, and 3.00 μΩ cm at 0, 90, and 293 K, respectively.
29	62	Kemp, W.R.G., et al.	1957	L	2.2-91			10.26	Similar to the above specimen except electrical resistivity reported as 1.94, 2.31, and 3.89 μΩ cm at 0, 90, and 293 K, respectively.
30	89	Kemp, W.R.G., et al.	1959	L	2.0-91	1		32	α-brass; machined from an annealed and torsionally deformed bar; electrical resistivity 4.59, 5.11, and 7.27 μΩ cm at 4.2, 90, and 293 K, respectively.
31	89	Kemp, W.R.G., et al.	1959	L	6.5-91	2			Similar to the above specimen except annealed (after machining) up to 250 C at a rate of 6 C min⁻¹; electrical resistivity 4.20, 4.84, and 6.88 μΩ cm at 4.2, 90, and 293 K, respectively.
32	89	Kemp, W.R.G., et al.	1959	L	2.1-91	3			Similar to the above specimen except annealed (after machining) up to 290 C at a rate of 6 C min⁻¹; electrical resistivity 3.90, 4.49, and 6.58 μΩ cm at 4.2, 90, and 293 K, respectively.
33	89	Kemp, W.R.G., et al.	1959	K	2.0-91	4			Similar to the above specimen except annealed after machining up to 400 C at a rate of 6 C min⁻¹; electrical resistivity 3.66, 4.27, and 6.31 μΩ cm at 4.2, 90, and 293 K, respectively.
34	63	Sodström, E.	1919	T	273, 373		92.65	7.35	Rolled and drawn; annealed close to the melting point for 0.5 hr.
35	63	Sodström, E.	1919	T	273, 373		85.65	14.35	Similar to the above specimen.
36	63	Sodström, E.	1919	T	273, 373		72.11	27.89	Similar to the above specimen.
37	63	Sodström, E.	1919	T	273, 373		66.97	33.03	Similar to the above specimen.

TABLE 16. THERMAL CONDUCTIVITY OF COPPER - ZINC ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
38	154	Eucken, A. and Neumann, O.	1924	L	90, 273	Red brass	82	18	Polycrystalline; grain size 0.006 cm^2; electrical conductivity 26.95 and 17.50 x 10^4 Ω^{-1} cm^{-1} at 90 and 273 K, respectively.
39	154	Eucken, A. and Neumann, O.	1924	L	90, 273	Red brass	82	18	Polycrystalline; grain size 0.11 cm^2; electrical conductivity 27.36 and 17.75 x 10^4 Ω^{-1} cm^{-1} at 90 and 273 K, respectively.
40	155	Lomer, J.N. and Rosenberg, H.M.	1959	L	2.3-4.4	Brass	85	15	α-brass; 2.5 mm diameter and 4 cm long; prepared from Johnson Matthey spectrographically standardized metals by melting in vacuo, cooling, and swaging; annealed just below melting point for 40 hr.
41	155	Lomer, J.N. and Rosenberg, H.M.	1959	L	2.3-4.5	Brass			The above specimen drawn to produce 4.6% strain.
42	155	Lomer, J.N. and Rosenberg, H.M.	1959	L	2.4-4.5	Brass			The above specimen drawn to produce 10.4% strain.
43	155	Lomer, J.N. and Rosenberg, H.M.	1959	L	2.3-4.4	Brass			The above specimen drawn to produce 19.8% strain.
44	156	Aoyama, S. and Ito, T.	1940	L, R	78, 273	1	95.46	4.54	Prepared from electrolytic copper containing impurities: 0.015 Sb, 0.010 Fe, 0.007 S, 0.0008 As, and 0.0008 Pb; α-brass; annealed in N_2 for 20 hr at 380-400 C; electrical conductivity 6.00 and 3.25 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
45	156	Aoyama, S. and Ito, T.	1940	L, R	78, 273	2	92.82	7.18	Similar to the above specimen except electrical conductivity 4.59 and 2.71 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
46	156	Aoyama, S. and Ito, T.	1940	L, R	78, 273	3	86.87	13.13	Similar to the above specimen except electrical conductivity 3.56 and 2.29 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
47	156	Aoyama, S. and Ito, T.	1940	L, R	78, 273	4	82.58	17.42	Similar to the above specimen except electrical conductivity 3.08 and 2.03 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
48	156	Aoyama, S. and Ito, T.	1940	L, R	78, 273	5	79.73	20.27	Similar to the above specimen except electrical conductivity 3.04 and 1.99 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
49	156	Aoyama, S. and Ito, T.	1940	L, R	78, 273	6	75.44	24.56	Similar to the above specimen except electrical conductivity 2.83 and 1.87 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
50	156	Aoyama, S. and Ito, T.	1940	L, R	73, 273	7	70	30	Similar to the above specimen except electrical conductivity 2.46 and 1.64 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
51	156	Aoyama, S. and Ito, T.	1940	L, R	73, 273	8	64.05	35.95	Similar to the above specimen except electrical conductivity 2.39 and 1.57 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
52	156	Aoyama, S. and Ito, T.	1940	L, R	73, 273	9	62.30	37.70	Prepared from the same orignal materials by the same fabrication method; $\alpha+\beta$-brass; electrical conductivity 2.63 and 1.61 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
53	156	Aoyama, S. and Ito, T.	1940	L, R	73, 273	10	59.93	40.07	Similar to the above specimen except electrical conductivity 3.28 and 1.76 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
54	156	Aoyama, S. and Ito, T.	1940	L, R	73, 273	11	55.62	44.38	Similar to the above specimen except electrical conductivity 4.73 and 2.05 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.
55	156	Aoyama, S. and Ito, T.	1940	L, R	73, 273	12	51.09	48.91	β-brass; prepared from the same original materials by the same fabrication method; electrical conductivity 8.25 and 2.50 x 10^5 Ω^{-1} cm^{-1} at 78 and 273 K, respectively.

TABLE 18. THERMAL CONDUCTIVITY OF COPPER + ZINC ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
56	157	Olsen, T.	1960	L	1.3-4.2	Z4	95.4	4.59	0.01 Pb; cylindrical specimen 10 cm long; machined; annealed for 21 hr at 540 C; electrical resistivity 1.13 and 1.08 μΩ cm at 1.05 and 4.2 K, respectively.
57	157	Olsen, T.	1960	L	1.3-4.2	Z15	84.53	15.43	0.02 Fe and 0.02 Pb; cylindrical specimen 10 cm long; machined; annealed for 21 hr at 540 C; electrical resistivity 2.55 and 2.36 μΩ cm at 1.05 and 4.2 K, respectively.
58	157	Olsen, T.	1960	L	1.4-4.2	Z20	86.56	13.43	0.01 Fe; cylindrical specimen 10 cm long; cold-worked and machined; annealed at 500 C for 17 hr; electrical resistivity 2.73 and 2.58 μΩ cm at 1.05 and 4.2 K, respectively.
59	157	Olsen, T.	1960	L	1.3-4.1	Z30	69.95	30.02	0.02 Fe and 0.01 Pb; cylindrical specimen 10 cm long; machined; annealed for 21 hr at 540 C; electrical resistivity 4.22 and 4.10 μΩ cm at 1.05 and 4.2 K, respectively.
60	158	Gordon, J.E. and Amstutz, L.I.	1965		1.1-4.1	CDA alloy; No. 260	69.3 ± 0.5	30.7 ± 0.5	0.07 Si, 0.025 Pb, < 0.01 each of Fe, Co, and Ni; strip specimen 0.0150 cm in cross-section and 3.46 cm long; supplied by Chase Brass and Copper Co.; cold-rolled cartridge brass of nominal grain size 0.025-0.050 mm; electrical resistivity 3.78 and 6.65 μΩ cm at 4.2 K and room temperature, respectively.
61	123	Materials in Design Engineering	1959		293.2	Gliding	94.0-96.0	Bal.	Nominal composition; density 8.86 g cm^{-3}.
62	123	Materials in Design Engineering	1959		293.2	Commercial bronze	89.0-91.0	Bal.	Nominal composition; density 8.80 g cm^{-3}.
63	123	Materials in Design Engineering	1959		293.2	Red brass	84.0-86.0	Bal.	Nominal composition; density 8.75 g cm^{-3}.
64	123	Materials in Design Engineering	1959		293.2	Low brass	78.5-81.5	Bal.	Nominal composition; density 8.66 g cm^{-3}.
65	123	Materials in Design Engineering	1959		293.2	Cartridge brass	68.5-71.5	Bal.	Nominal composition; density 8.53 g cm^{-3}.
66	123	Materials in Design Engineering	1959		293.2	Muntz metal	59.0-63.0	Bal.	Nominal composition; density 8.39 g cm^{-3}.
67	83	Kierspe, W.	1967	L	293.2			1.54	Cylindrical specimen.
68	159	Srivastava, B.N., Chatterjee, S., and Sen, S.K.	1969	L	17-92			1.96	Prepared from spectrographically pure rods of copper and zinc, supplied by Johnson Matthey and Co., Ltd, by sealing the metals in appropriate portion in an evacuated quartz tube, heating to 1100 C, shaking thoroughly, cooling to 900 C and maintaining for 5 days, rolled, annealed at 500 C for 6 hr; residual electrical resistivity 0.549 μΩ cm.
69	159	Srivastava, B.N., et al.	1969	L	18-91			4.76	Same fabrication method as the above specimen; residual electrical resistivity 1.043 μΩ cm.
70	44	Griffiths, E. and Schofield, F.H.	1928	L	337-498	Bar 4	60.7	38.5	0.5 Sn and 0.30 Mn; 1 in. diameter and 15 in. long; electrical resistivity 9.3, 9.6, 10.0, 10.4, 10.9, and 11.3 μΩ cm at 20, 75, 100, 150, 200, and 250 C, respectively.
71*	92	Smith, C.S.	1930	L	405-515	Bar 55	81.18	18.63	0.20 Sn, 0.02 Fe, and trace Pb; 0.750 in. diameter and 13.25 in. long; annealed at 700 C for 2 hr; electrical conductivity 18.674 x 10^4 $\Omega^{-1} cm^{-1}$ at 20 C.

* Not shown in figure.

TABLE 18. THERMAL CONDUCTIVITY OF COPPER + ZINC ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
72	92	Smith, C.S.	1930	L	321-508	Bar 56	71.09	27.77	1.02 Sn, 0.02 Fe, and trace Pb; 0.750 in. diameter and 13.25 in. long; annealed at 700 C for 45 min; electrical conductivity 14.298 x 10^4 Ω^{-1} cm^{-1} at 20 C.
73*	92	Smith, C.S.	1930	L	320-517	Bar 57	59.85	39.36	0.70 Sn, 0.07 Pb, and 0.02 Fe; 0.750 in. diameter and 13.25 in. long; annealed at 650 C for 3 hr; electrical conductivity 15.146 x 10^4 Ω^{-1} cm^{-1} at 20 C.
74	159	Donaldson, J.W.	1925	L	363-702	70:30 brass	70.29	28.71	0.35 Sn, 0.34 Pb, and 0.31 Fe; 0.75 in. diameter and 15.5 in. long; machined from a dry sand-cast bar.
75	160	Tadokoro, Y.	1936	P	479-888	Brass	71.00	28.43	0.25 Pb, 0.24 Fe, and trace Ni and Si; 110 x 110 x 70 mm; annealed at 650 C for 1.5 hr; density 8.062 g cm^{-3}; thermal conductivity values calculated from measured thermal diffusivity, specific heat capacity, and density data.
76	52	Charsley, P., Salter, J.A.M., and Leaver, A.D.W.	1968	L	1.8-4.2	α-brass		27.8	Polycrystalline; supplied by the International Research and Development Co., Ltd.; prepared by induction melting; annealed in vacuum at 750 C for 15 hrs, furnace cooled.
77	52	Charsley, P., et al.	1968	L	1.7-4.2	α-brass			The above specimen deformed by tensile strain of 4.4%.
78	120	Leaver, A.D.W. and Charsley, P.	1971	L	2.1-4.1	30 Zn			Similar to the specimen for curve No. 76; deformed by tensile strain of 3.2%.
79	161	Lomer, J.N.	1958		10-100	0.1 Zn	99.9	0.1	Data taken from smooth curve presented by H.M. Rosenberg [180].
80	161	Lomer, J.N.	1958		10-100	1.0 Zn	99.0	1.0	Similar to above.
81	161	Lomer, J.N.	1958		10-100	2.0 Zn	98.0	2.0	Similar to above.
82	161	Lomer, J.N.	1958		10-100	3.0 Zn	97.0	3.0	Similar to above.
83	161	Lomer, J.N.	1958		10-100	4.5 Zn	95.5	4.5	Similar to above.
84	161	Lomer, J.N.	1958		10-100	7.2 Zn	92.8	7.2	Similar to above.
85	161	Lomer, J.N.	1958		10-100	10.0 Zn	90.0	10.0	Similar to above.
86	161	Lomer, J.N.	1958		10-100	25.5 Zn	74.5	25.5	Similar to above.
87*	172	Kapoor, A., Rowlands, J.A., and Woods, S.B.	1974	L	0.57-4.0	α-Brass	69.4	30.6	Calculated composition (30 a/o Zn); 4 mm diameter x 12 cm long; cast in air, swaged to 0.25 in. diameter, and machined to size; cold worked; residual electrical resistivity 4.59 μΩ cm.
88*	172	Kapoor, A., et al.	1974	L	0.52-3.9	α-Brass			The above specimen annealed in argon at 600 K for 12 hr; residual electrical resistivity 3.82 μΩ cm.
89*	172	Kapoor, A., et al.	1974	L	0.71-4.0	α-Brass			The above specimen reannealed in argon at 700 K for 12 hr; residual electrical resistivity 3.77 μΩ cm.
90*	172	Kapoor, A., et al.	1974	L	0.73-4.0	α-Brass			The above specimen reannealed in argon at 1000 K for 12 hr; residual electrical resistivity 3.86 μΩ cm.
91*	172	Kapoor, A., et al.	1974	L	0.68-4.0	Brass			Single crystal; 3 mm diameter x 15 cm long; obtained from Windsor Metal Crystals Inc., Md.; residual electrical resistivity 3.53 μΩ cm.

* Not shown in figure.

4.7. Gold-Palladium Alloy System

The gold-palladium alloy system forms a continuous series of solid solutions over the entire range of compositions and is free from the complicating effects of any kind of transitions.

There are 14 sets of experimental data available for the thermal conductivity of this alloy system. However, of the nine data sets available for Au + Pd alloys listed in Table 20 and shown in Figure 29, five sets are merely single data points at room temperature, and all the five data sets available for Pd + Au alloys are single data points at room temperature, as listed in Table 21 and shown in Figure 30.

The thermal conductivity of these alloys was first investigated by Schulze [93] (Au + Pd curves 1-5 and Pd + Au curves 1-5) who measured the room-temperature thermal conductivity of these alloys at intervals of 10%. These values, which include the only experimental values for this system for palladium concentrations greater than 40%, are thought to be more than 20% too high in some cases. This judgment is based primarily on the fact that interpolation between the values for 30 and 40% Pd yields a value 27% greater than that obtained by Laubitz and van der Meer [85] (Au + Pd curve 8) on a specimen containing 34.95% Pd and is supported by the fact that, after correcting for the lattice component, the Lorenz ratio for the specimen containing 40% Pd (55.24 At.% Pd) is 30% greater than the classical values. It is unlikely that band structure effects could cause such a large deviation from the classical value for this composition at 298 K.

In contrast to this, the early measurements by Grüneisen and Reddemann [61] of the thermal conductivity at liquid hydrogen and liquid nitrogen temperatures of specimens containing 5, 10, and 39.9% Pd (Au + Pd curves 6-8) are thought to be close to the true values. The values calculated from eqs. (12) and (35) are in good agreement with these measurements at those temperatures for which it was possible to calculate the lattice component. The investigation by Fletcher and Greig [84] of the thermal conductivity of palladium-silver alloys revealed that the strong electron-phonon interaction in palladium-rich alloys suppresses the low temperature lattice thermal conductivity, causing its maximum to occur at much higher temperatures than in silver-rich alloys. This elevation of the temperature of the maximum of the lattice component is believed to occur also in this alloy system; the evidence for this is that while the calculated and experimental values for the 5, 10, and 39.9% Pd (8.88, 17.06, and 55.24 At.% Pd) alloys differ by less than 5% at 80 K and the measured values at liquid hydrogen temperatures of the 5 and 10% Pd specimens are consistent with the calculated values at 30 K, the measured value for the 39.9% Pd specimen is far below the calculated value for 30 K when the expression for the lattice component at temperatures above that of its maximum is used.

At high temperatures the only measurements are those of Laubitz and van der Meer [85], but these range from 300 to 1200 K and provide a test of the temperature dependence of the calculated values of the thermal conductivity of these alloys in this region. While the slope of the calculated curve is slightly steeper than that of the experimental curve, the largest discrepancy between the calculated and experimental values is less than 7%; in view of the 3.5% experimental error estimated for these measurements this is considered satisfactory agreement.

The recommended values for k, k_e, and k_g are tabulated in Table 19 for 25 alloy compositions. These values are for well-annealed alloys. The k_e values cover the full range of temperature from 4 to 1200 K, whereas the k and k_g values are not given for low temperatures. The values for k are also shown in Figures 27 and 28 and their uncertainties are stated in a footnote to Table 19, in which the values of residual electrical resistivity for the alloys are also given. The uncertainties of the k_e and k_g values are indicated by their being designated as recommended or provisional values. The ranges of uncertainties of recommended and provisional values are less than ±15% and between ±15 and ±30%, respectively.

TABLE 19. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 99.50% (99.08 At.%) Pd: 0.50% (0.92 At.%)			
ρ_0 = 0.3500 μΩcm			
T	k	k_e	k_g
4		0.279	
6		0.419	
8		0.558	
10		0.698	
15		1.05	
20		1.40	
25		1.39	
30	1.57*	1.48	0.0917
40	1.68*	1.60	0.0854
50	1.79*	1.71	0.0793
60	1.88*	1.81	0.0736
70	1.96*	1.90	0.0684
80	2.02*	1.95	0.0638
90	2.10*	2.04	0.0597
100	2.16*	2.10	0.0561
150	2.42*	2.37	0.0429
200	2.55*	2.52	0.0348
250	2.64*	2.61	0.0292
273	2.66*	2.63	0.0272
300	2.68*	2.66	0.0252
350	2.72*	2.69	0.0222
400	2.75*	2.73	0.0196
500	2.80*	2.78	0.0163
600	2.79*	2.77	0.0139
700	2.75*	2.74	0.0121
800	2.71*	2.70	0.0107
900	2.65*	2.64	0.0959
1000	2.60*	2.59	0.00870
1100	2.53*	2.52	0.00796
1200	2.47*	2.46	0.00733

Au: 99.00% (98.16 At.%) Pd: 1.00% (1.84 At.%)			
ρ_0 = 0.680 μΩcm			
T	k	k_e	k_g
4		0.144	
6		0.216	
8		0.287	
10		0.359	
15		0.539	
20		0.719	
25		0.784	
30	0.955*	0.878	0.0774
40	1.11*	1.04	0.0771
50	1.23*	1.17	0.0656
60	1.34*	1.28	0.0608
70	1.43*	1.38	0.0566
80	1.51*	1.46	0.0529
90	1.60*	1.55	0.0497
100	1.68*	1.64	0.0468
150	2.00*	1.97	0.0366
200	2.18*	2.15	0.0302
250	2.30*	2.28	0.0258
273	2.35*	2.33	0.0242
300	2.40*	2.37	0.0226
350	2.45*	2.43	0.0201
400	2.51*	2.49	0.0181
500	2.57*	2.55	0.0152
600	2.62*	2.61	0.0130
700	2.62*	2.61	0.0115
800	2.59*	2.58	0.0102
900	2.54*	2.54	0.00923
1000	2.52*	2.51	0.00841
1100	2.46*	2.45	0.00773
1200	2.41*	2.40	0.00715

Au: 97.00% (94.58 At.%) Pd: 3.00% (5.42 At.%)			
ρ_0 = 2.010 μΩcm			
T	k	k_e	k_g
4		0.0486	
6		0.0729	
8		0.0972	
10		0.122	
15		0.182	
20		0.243	
25		0.292	
30	0.401*	0.342	0.0593
40	0.489*	0.436	0.0534
50	0.567*	0.518	0.0488
60	0.643*	0.598	0.0451
70	0.715*	0.673	0.0419
80	0.779*	0.740	0.0392
90	0.846*	0.809	0.0369
100	0.910*	0.875	0.0349
150	1.19*	1.16	0.0278
200	1.40*	1.38	0.0234
250	1.57*	1.55	0.0203
273	1.63*	1.61	0.0192
300	1.70*	1.69	0.0181
350	1.81*	1.79	0.0163
400	1.91*	1.89	0.0149
500	2.04*	2.03	0.0128
600	2.14*	2.13	0.0113
700	2.20*	2.19	0.0101
800	2.22*	2.21	0.00914
900	2.23*	2.22	0.00837
1000	2.23*	2.22	0.00772
1100	2.21*	2.21	0.00717
1200	2.19*	2.18	0.00670

Au: 95.00% (91.12 At.%) Pd: 5.00% (8.88 At.%)			
ρ_0 = 3.270 μΩcm			
T	k	k_e	k_g
4		0.0299	
6		0.0448	
8		0.0598	
10		0.0747	
15		0.112	
20		0.149	
25		0.182	
30	0.269	0.216	0.0535
40	0.328	0.280	0.0479
50	0.382	0.339	0.0436
60	0.436	0.396	0.0402
70	0.488	0.451	0.0374
80	0.537	0.502	0.0350
90	0.587	0.554	0.0329
100	0.635*	0.604	0.0312
150	0.857*	0.832	0.0249
200	1.04*	1.02	0.0211
250	1.20*	1.18	0.0184
273	1.27*	1.25	0.0175
300	1.33*	1.32	0.0165
350	1.45*	1.43	0.0150
400	1.55*	1.54	0.0137
500	1.70*	1.69	0.0119
600	1.82*	1.81	0.0105
700	1.90*	1.89	0.00949
800	1.95*	1.94	0.00866
900	1.99*	1.98	0.00797
1000	2.01*	2.00	0.00740
1100	2.01*	2.01	0.00691
1200	2.00*	2.00	0.00649

† Uncertainties of the total thermal conductivity, k, are as follows:
99.50 Au - 0.50 Pd: ±10% at moderate temperature and above ±10% at extreme temperature.
99.00 Au - 1.00 Pd: ±10% at moderate temperature and above ±10% at extreme temperature.
97.00 Au - 3.00 Pd: ±10% at moderate temperature and above ±10% at extreme temperature.
95.00 Au - 5.00 Pd: ±10% at moderate temperature and above ±10% at extreme temperature.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 19. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (continued) †

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 90.00% (82.94 At.%) Pd: 10.00% (17.06 At.%)				Au: 85.00% (75.38 At.%) Pd: 15.00% (24.62 At.%)				Au: 80.00% (68.36 At.%) Pd: 20.00% (31.64 At.%)				Au: 75.00% (61.84 At.%) Pd: 25.00% (38.16 At.%)			
ρ_0 = 6.160 μΩcm				ρ_0 = 8.65 μΩcm				ρ_0 = 10.85 μΩcm				ρ_0 = 12.74 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.0159		4		0.0113		4		0.00901		4		0.00767	
6		0.0238		6		0.0169		6		0.0135		6		0.0115	
8		0.0317		8		0.0226		8		0.0180		8		0.0153	
10		0.0397		10		0.0282		10		0.0225		10		0.0192	
15		0.0595		15		0.0424		15		0.0338		15		0.0288	
20		0.0793		20		0.0565		20		0.0450		20		0.0384	
25		0.0965		25		0.0694		25		0.0554		25		0.0474	
30	0.164	0.115	0.0489	30		0.0829		30		0.0663		30		0.0566	
40	0.195	0.151	0.0435	40	0.152*	0.109	0.0429	40		0.0876		40		0.0749	
50	0.226	0.187	0.0396	50	0.174*	0.135	0.0389	50	0.148*	0.109	0.0396	50		0.0929	
60	0.258	0.222	0.0363	60	0.197*	0.161	0.0358	60	0.166*	0.129	0.0364	60	0.148*	0.111	0.0376
70	0.290	0.256	0.0336	70	0.220*	0.186	0.0333	70	0.184*	0.150	0.0339	70	0.163*	0.128	0.0350
80	0.320	0.289	0.0316	80	0.242*	0.211	0.0312	80	0.202*	0.170	0.0317	80	0.178*	0.146	0.0328
90	0.351	0.322	0.0296	90	0.265*	0.235	0.0294	90	0.220*	0.190	0.0299	90	0.194*	0.163	0.0310
100	0.383*	0.354	0.0282	100	0.287*	0.259	0.0279	100	0.238*	0.209	0.0284	100	0.209*	0.180	0.0294
150	0.529*	0.506	0.0227	150	0.397*	0.375	0.0225	150	0.327*	0.304	0.0230	150	0.285*	0.261	0.0238
200	0.660*	0.640	0.0193	200	0.500*	0.481	0.0192	200	0.412*	0.392	0.0196	200	0.357*	0.337	0.0204
250	0.778*	0.761	0.0170	250	0.594*	0.577	0.0169	250	0.491*	0.473	0.0173	250	0.423*	0.406	0.0180
273	0.829*	0.813	0.0161	273	0.635*	0.169	0.0161	273	0.525*	0.509	0.0165	273	0.452*	0.436	0.0171
300	0.886	0.871	0.0153	300	0.682*	0.666	0.0152	300	0.565	0.549	0.0156	300	0.486*	0.470	0.0162
350	0.983*	0.969	0.0139	350	0.762*	0.748	0.0139	350	0.631*	0.617	0.0143	350	0.544*	0.529	0.0149
400	1.07*	1.06	0.0128	400	0.838*	0.826	0.0129	400	0.695*	0.682	0.0132	400	0.599*	0.586	0.0138
500	1.22*	1.21	0.0112	500	0.966*	0.955	0.0113	500	0.806*	0.795	0.0116	500	0.698*	0.686	0.0121
600	1.34*	1.33	0.00999	600	1.08*	1.07	0.0101	600	0.909*	0.899	0.0104	600	0.785*	0.774	0.0108
700	1.44*	1.43	0.00907	700	1.17*	1.16	0.00917	700	0.996*	0.986	0.00947	700	0.861*	0.851	0.00989
800	1.51*	1.50	0.00832	800	1.25*	1.24	0.00844	800	1.07*	1.06	0.00873	800	0.927*	0.918	0.00912
900	1.57*	1.56	0.00771	900	1.31*	1.30	0.00784	900	1.13*	1.12	0.00812	900	0.981*	0.973	0.00849
1000	1.61*	1.61	0.00720	1000	1.37*	1.36	0.00733	1000	1.19*	1.18	0.00760	1000	1.03*	1.02	0.00796
1100	1.64*	1.64	0.00676	1100	1.41*	1.40	0.00690	1100	1.23*	1.22	0.00716	1100	1.06*	1.05	0.00750
1200	1.66*	1.66	0.00637	1200	1.43*	1.43	0.00652	1200	1.26*	1.25	0.00678	1200	1.09*	1.09	0.00711

† Uncertainties of the total thermal conductivity, k, are as follows:
90.00 Au - 10.00 Pd: ±10% at moderate temperature and above ±10% at extreme temperature.
85.00 Au - 15.00 Pd: ±10% at moderate temperature and above ±10% at extreme temperature.
80.00 Au - 20.00 Pd: ±10% at moderate temperature and above ±10% at extreme temperature.
75.00 Au - 25.00 Pd: ±10% at moderate temperature and above ±10% at extreme temperature.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 19. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 70.00% (55.76 At.%) Pd: 30.00% (44.24 At.%)				Au: 65.00% (50.08 At.%) Pd: 35.00% (49.92 At.%)			
ρ_0 = 15.00 μΩ cm				ρ_0 = 20.57 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g
4		0.00652		4		0.00475	
6		0.00977		6		0.00713	
8		0.0130		8		0.00950	
10		0.0163		10		0.0119	
15		0.0244		15		0.0178	
20		0.0326		20		0.0238	
25		0.0402		25		0.0294	
30		0.0481		30		0.0352	
40		0.0637		40		0.0466	
50		0.0790		50		0.0579	
60	0.133*	0.0942	0.0393	60		0.0688	
70	0.146*	0.109	0.0365	70		0.0797	
80	0.158*	0.124	0.0343	80	0.127*	0.0905	0.0360
90	0.172*	0.139	0.0323	90	0.135*	0.101	0.0340
100	0.184*	0.153	0.0307	100	0.144*	0.112	0.0323
150	0.246*	0.221	0.0249	150	0.188*	0.162	0.0262
200	0.306*	0.285	0.0213	200	0.231*	0.209	0.0224
250	0.361*	0.342	0.0188	250	0.272*	0.252	0.0199
273	0.385*	0.367	0.0179	273	0.290*	0.271	0.0189
300	0.412*	0.395	0.0170	300	0.311	0.293	0.0179
350	0.461*	0.445	0.0156	350	0.349	0.333	0.0164
400	0.507*	0.492	0.0144	400	0.387	0.371	0.0152
500	0.589*	0.577	0.0127	500	0.460	0.447	0.0134
600	0.662*	0.651	0.0114	600	0.531	0.519	0.0120
700	0.729*	0.719	0.0104	700	0.599	0.588	0.0110
800	0.789*	0.779	0.00959	800	0.660	0.650	0.0101
900	0.842*	0.833	0.00893	900	0.716	0.706	0.00944
1000	0.888*	0.880	0.00838	1000	0.767	0.758	0.00885
1100	0.930*	0.922	0.00790	1100	0.815	0.807	0.00835
1200	0.972*	0.965	0.00749	1200	0.864	0.856	0.00792

Au: 60.00% (44.76 At.%) Pd: 40.00% (55.24 At.%)				Au: 55.00% (39.77 At.%) Pd: 45.00% (60.23 At.%)			
ρ_0 = 23.55 μΩ cm				ρ_0 = 23.19 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g
4		0.00415		4		0.00421	
6		0.00622		6		0.00632	
8		0.00830		8		0.00843	
10		0.0104		10		0.0105	
15		0.0156		15		0.0158	
20		0.0207		20		0.0211	
25		0.0257		25		0.0261	
30		0.0306		30		0.0312	
40		0.0408		40		0.0413	
50		0.0507		50		0.0512	
60		0.0605		60		0.0606	
70		0.0701		70		0.0703	
80	0.117	0.0793	0.0381	80		0.0796	
90	0.125	0.0887	0.0360	90		0.0889	
100	0.132*‡	0.0980‡	0.0341‡	100		0.0976	
150	0.169*‡	0.142‡	0.0277‡	150	0.169*‡	0.140‡	0.0295‡
200	0.206*‡	0.182‡	0.0238‡	200	0.204*‡	0.178‡	0.0253‡
250	0.240*‡	0.219‡	0.0210‡	250	0.236*‡	0.213‡	0.0224‡
273	0.256*‡	0.236‡	0.0200‡	273	0.250*‡	0.229‡	0.0213‡
300	0.274‡	0.255‡	0.0190‡	300	0.267*‡	0.247‡	0.0202‡
350	0.308*‡	0.291‡	0.0174‡	350	0.298*‡	0.280‡	0.0185‡
400	0.341*‡	0.325‡	0.0161‡	400	0.328*‡	0.311‡	0.0172‡
500	0.405*‡	0.391‡	0.0142‡	500	0.385*‡	0.370‡	0.0151‡
600	0.467*‡	0.455‡	0.0128‡	600	0.441*‡	0.427‡	0.0136‡
700	0.528*‡	0.517‡	0.0118‡	700	0.495*‡	0.483‡	0.0124‡
800	0.587*‡	0.576‡	0.0107‡	800	0.546*‡	0.535‡	0.0114‡
900	0.640*‡	0.630‡	0.0100‡	900	0.593*‡	0.582‡	0.0107‡
1000	0.688*‡	0.679‡	0.00939‡	1000	0.634*‡	0.624‡	0.0100‡
1100	0.734*‡	0.725‡	0.00886‡	1100	0.680*‡	0.671‡	0.00943‡
1200	0.782*‡	0.773‡	0.00840‡	1200	0.724*‡	0.715‡	0.00894‡

† Uncertainties of the total thermal conductivity, k, are as follows:
70.00 Au - 30.00 Pd: ±10% at moderate temperatures and above ±10% at extreme temperatures.
65.00 Au - 35.00 Pd: ±10% at moderate temperatures and above ±10% at extreme temperatures.
60.00 Au - 40.00 Pd: ±15% at moderate temperatures and above ±15% at extreme temperatures.
55.00 Au - 45.00 Pd: ±15%.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 19. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (continued) †

[Temperature, T, K; Thermal Conductivity, k, W cm⁻¹ K⁻¹; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 50.00% (35.07 At.%) Pd: 50.00% (64.93 At.%)				Au: 45.00% (30.65 At.%) Pd: 55.00% (69.35 At.%)				Au: 40.00% (26.48 At.%) Pd: 60.00% (73.52 At.%)				Au: 35.00% (22.53 At.%) Pd: 65.00% (77.47 At.%)			
ρ_0 = 21.54 μΩcm				ρ_0 = 19.33 μΩcm				ρ_0 = 17.00 μΩcm				ρ_0 = 14.70 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.00454		4		0.00505		4		0.00575		4		0.00665	
6		0.00681		6		0.00758		6		0.00862		6		0.00997	
8		0.00907		8		0.0101		8		0.0115		8		0.0133	
10		0.0113		10		0.0126		10		0.0144		10		0.0166	
15		0.0170		15		0.0190		15		0.0216		15		0.0249	
20		0.0227		20		0.0253		20		0.0287		20		0.0332	
25		0.0281		25		0.0313		25		0.0353		25		0.0406	
30		0.0336		30		0.0373		30		0.0421		30		0.0486	
40		0.0444		40		0.0492		40		0.0553		40		0.0635	
50		0.0548		50		0.0605		50		0.0678		50		0.0776	
60		0.0649		60		0.0714		60		0.0798		60		0.0908	
70		0.0748		70		0.0820		70		0.0914		70		0.103	
80		0.0845		80		0.0923		80		0.103		80		0.116	
90		0.0941		90		0.102		90		0.114		90		0.127	
100		0.103		100		0.112		100		0.124		100		0.139	
150	0.179*‡	0.148‡	0.0315‡	150		0.156		150		0.170		150		0.187	
200	0.211*‡	0.184‡	0.0270‡	200	0.223*‡	0.194‡	0.0290‡	200	0.241*‡	0.209‡	0.0314‡	200	0.261*‡	0.227‡	0.0342‡
250	0.242*‡	0.218‡	0.0239‡	250	0.254*‡	0.228‡	0.0257‡	250	0.271*‡	0.243‡	0.0278‡	250	0.291*‡	0.261‡	0.0302‡
273	0.255*‡	0.232‡	0.0228‡	273	0.267*‡	0.242‡	0.0245‡	273	0.284*‡	0.258‡	0.0265‡	273	0.304*‡	0.275‡	0.0288‡
300	0.271‡	0.249‡	0.0216‡	300	0.283*‡	0.260‡	0.0232‡	300	0.300‡	0.274‡	0.0251‡	300	0.319*‡	0.292‡	0.0273‡
350	0.301*‡	0.281‡	0.0198‡	350	0.312*‡	0.291‡	0.0213‡	350	0.329*‡	0.306‡	0.0230‡	350	0.349*‡	0.324‡	0.0250‡
400	0.329*‡	0.311‡	0.0184‡	400	0.340*‡	0.320‡	0.0197‡	400	0.357*‡	0.335‡	0.0213‡	400	0.374*‡	0.351‡	0.0231‡
500	0.383*‡	0.367‡	0.0161‡	500	0.392*‡	0.375‡	0.0173‡	500	0.409*‡	0.391‡	0.0187‡	500	0.432*‡	0.412‡	0.0203‡
600	0.435*‡	0.420‡	0.0145‡	600	0.442*‡	0.426‡	0.0156‡	600	0.459*‡	0.443‡	0.0168‡	600	0.482*‡	0.464‡	0.0183‡
700	0.483*‡	0.470‡	0.0132‡	700	0.488*‡	0.474‡	0.0142‡	700	0.506*‡	0.490‡	0.0153‡	700	0.528*‡	0.512‡	0.0166‡
800	0.529*‡	0.517‡	0.0122‡	800	0.531*‡	0.518‡	0.0131‡	800	0.549*‡	0.535‡	0.0141‡	800	0.570*‡	0.554‡	0.0153‡
900	0.572*‡	0.561‡	0.0114‡	900	0.571*‡	0.559‡	0.0122‡	900	0.588*‡	0.575‡	0.0132‡	900	0.609*‡	0.594‡	0.0143‡
1000	0.615*‡	0.604‡	0.0107‡	1000	0.609*‡	0.598‡	0.0115‡	1000	0.626*‡	0.614‡	0.0123‡	1000	0.646*‡	0.633‡	0.0134‡
1100	0.657*‡	0.647‡	0.0101‡	1100	0.639*‡	0.628‡	0.0106‡	1100	0.663*‡	0.652‡	0.0116‡	1100	0.683*‡	0.671‡	0.0126‡
1200	0.701*‡	0.692‡	0.00955‡	1200	0.686*‡	0.676‡	0.0102‡	1200	0.700*‡	0.689‡	0.0110‡	1200	0.719*‡	0.707‡	0.0120‡

† Uncertainties of the total thermal conductivity, k, are as follows:

- 50.00 Au - 50.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.
- 45.00 Au - 55.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.
- 40.00 Au - 60.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.
- 35.00 Au - 65.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 19. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (continued) †

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 30.00% (18.80 At.%) Pd: 70.00% (81.20 At.%)				Au: 25.00% (15.26 At.%) Pd: 75.00% (84.74 At.%)				Au: 20.00% (11.90 At.%) Pd: 80.00% (88.10 At.%)				Au: 15.00% (8.70 At.%) Pd: 85.00% (91.30 At.%)			
ρ_0 = 13.00 μΩcm				ρ_0 = 10.19 μΩcm				ρ_0 = 8.00 μΩcm				ρ_0 = 5.850 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.00752		4		0.00959		4		0.0122		4		0.0167	
6		0.0113		6		0.0144		6		0.0183		6		0.0251	
8		0.0150		8		0.0192		8		0.0244		8		0.0334	
10		0.0188		10		0.0240		10		0.0305		10		0.0417	
15		0.0282		15		0.0360		15		0.0458		15		0.0626	
20		0.0376		20		0.0479		20		0.0611		20		0.0835	
25		0.0459		25		0.0584		25		0.0741		25		0.0993	
30		0.0545		30		0.0692		30		0.0876		30		0.116	
40		0.0710		40		0.0897		40		0.112		40		0.147	
50		0.0864		50		0.108		50		0.134		50		0.173	
60		0.101		60		0.125		60		0.153		60		0.194	
70		0.114		70		0.140		70		0.170		70		0.214	
80		0.128		80		0.155		80		0.187		80		0.232	
90		0.140		90		0.170		90		0.202		90		0.250	
100		0.152		100		0.183		100		0.216		100		0.264	
150		0.202		150		0.236		150		0.271		150		0.317	
200	0.280*‡	0.243‡	0.0376‡	200	0.319*‡	0.278‡	0.0418‡	200	0.360*‡	0.313‡	0.0472‡	200		0.355	
250	0.311*‡	0.277‡	0.0332‡	250	0.349*‡	0.312‡	0.0369‡	250	0.387*‡	0.345‡	0.0417‡	250	0.433*‡	0.384‡	0.0482‡
273	0.324*‡	0.292‡	0.0316‡	273	0.361*‡	0.326‡	0.0351‡	273	0.399*‡	0.359‡	0.0396‡	273	0.443*‡	0.397‡	0.0458‡
300	0.341‡	0.311‡	0.0300‡	300	0.377*‡	0.344‡	0.0333‡	300	0.413‡	0.376‡	0.0375‡	300	0.457*‡	0.414‡	0.0434‡
350	0.372*‡	0.344‡	0.0274‡	350	0.408*‡	0.378‡	0.0304‡	350	0.444‡	0.410‡	0.0343‡	350	0.487*‡	0.447‡	0.0396‡
400	0.402*‡	0.377‡	0.0254‡	400	0.438*‡	0.409‡	0.0282‡	400	0.474‡	0.442‡	0.0317‡	400	0.516*‡	0.479‡	0.0366‡
500	0.459*‡	0.437‡	0.0223‡	500	0.492*‡	0.467‡	0.0247‡	500	0.528‡	0.500‡	0.0277‡	500	0.570*‡	0.538‡	0.0319‡
600	0.511*‡	0.491‡	0.0200‡	600	0.542*‡	0.520‡	0.0221‡	600	0.578‡	0.553‡	0.0248‡	600	0.619*‡	0.591‡	0.0285‡
700	0.557*‡	0.539‡	0.0182‡	700	0.588*‡	0.568‡	0.0201‡	700	0.626‡	0.604‡	0.0226‡	700	0.666*‡	0.640‡	0.0259‡
800	0.602*‡	0.585‡	0.0168‡	800	0.633*‡	0.615‡	0.0185‡	800	0.672‡	0.652‡	0.0208‡	800	0.709*‡	0.685‡	0.0237‡
900	0.645*‡	0.629‡	0.0156‡	900	0.677*‡	0.660‡	0.0172‡	900	0.717‡	0.698‡	0.0193‡	900	0.757*‡	0.735‡	0.0220‡
1000	0.681*‡	0.667‡	0.0146‡	1000	0.716*‡	0.700‡	0.0161‡	1000	0.756‡	0.738‡	0.0180‡	1000	0.797*‡	0.776‡	0.0205‡
1100	0.718*‡	0.704‡	0.0138‡	1100	0.754*‡	0.739‡	0.0152‡	1100	0.795‡	0.778‡	0.0169‡	1100	0.836*‡	0.817‡	0.0193‡
1200	0.753*‡	0.740‡	0.0130‡	1200	0.791*‡	0.776‡	0.0144‡	1200	0.832‡	0.816‡	0.0160‡	1200	0.871*‡	0.853‡	0.0182‡

† Uncertainties of the total thermal conductivity, k, are as follows:
30.00 Au - 70.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.
25.00 Au - 75.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.
20.00 Au - 80.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.
15.00 Au - 85.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 19. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 10.00% (5.66 At.%) Pd: 90.00% (94.34 At.%)				Au: 5.00% (2.76 At.%) Pd: 95.00% (97.24 At.%)			
ρ_0 = 3.850 μΩ cm				ρ_0 = 1.900 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g
4		0.0254		4		0.0514	
6		0.0381		6		0.0771	
8		0.0508		8		0.103	
10		0.0635		10		0.129	
15		0.0953		15		0.193	
20		0.127		20		0.257	
25		0.151		25		0.296	
30		0.175		30		0.337	
40		0.227		40		0.393	
50		0.247		50		0.418	
60		0.280		60		0.423	
70		0.288		70		0.430	
80		0.305		80		0.435	
90		0.322		90		0.444	
100		0.333		100		0.447	
150		0.377		150		0.462	
200		0.407		200		0.475	
250	0.489*‡	0.431‡	0.0582‡	250	0.566*‡	0.489‡	0.0775‡
273	0.497*‡	0.442‡	0.0553‡	273	0.571*‡	0.497‡	0.0734‡
300	0.509‡	0.457‡	0.0523‡	300	0.580*‡	0.510‡	0.0692‡
350	0.548*‡	0.500‡	0.0476‡	350	0.606*‡	0.544‡	0.0627‡
400	0.566*‡	0.522‡	0.0439‡	400	0.629*‡	0.572‡	0.0575‡
500	0.617*‡	0.578‡	0.0382‡	500	0.677*‡	0.627‡	0.0495‡
600	0.665*‡	0.631‡	0.0339‡	600	0.720*‡	0.677‡	0.0437‡
700	0.711*‡	0.681‡	0.0307‡	700	0.761*‡	0.722‡	0.0392‡
800	0.754*‡	0.726‡	0.0281‡	800	0.806*‡	0.770‡	0.0356‡
900	0.800*‡	0.774‡	0.0259‡	900	0.850*‡	0.817‡	0.0326‡
1000	0.841*‡	0.817‡	0.0241‡	1000	0.887*‡	0.857‡	0.0301‡
1100	0.880*‡	0.857‡	0.0226‡	1100	0.925*‡	0.897‡	0.0280‡
1200	0.918*‡	0.897‡	0.0213‡	1200	0.958*‡	0.932‡	0.0262‡

Au: 3.00% (1.64 At.%) Pd: 97.00% (98.36 At.%)				Au: 1.00% (0.54 At.%) Pd: 99.00% (99.46 At.%)			
ρ_0 = 1.100 μΩ cm				ρ_0 = 0.3800 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g
4		0.0888		4		0.257	
6		0.133		6		0.386	
8		0.178		8		0.514	
10		0.222		10		0.643	
15		0.333		15		0.964	
20		0.444		20		1.29	
25		0.483		25		1.16	
30		0.533		30		1.15	
40		0.576		40		1.03	
50		0.569		50		0.871	
60		0.560		60		0.762	
70		0.537		70		0.690	
80		0.527		80		0.663	
90		0.520		90		0.637	
100		0.515		100		0.615	
150		0.505		150		0.559	
200		0.508		200		0.545	
250	0.610*‡	0.517‡	0.0930‡	250		0.548	
273	0.612*‡	0.524‡	0.0879‡	273	0.671*‡	0.553‡	0.118‡
300	0.616*‡	0.534‡	0.0826‡	300	0.675*‡	0.565‡	0.110‡
350	0.650*‡	0.576‡	0.0745‡	350	0.691*‡	0.593‡	0.0977‡
400	0.662*‡	0.594‡	0.0679‡	400	0.706*‡	0.618‡	0.0878‡
500	0.704*‡	0.646‡	0.0579‡	500	0.739*‡	0.666‡	0.0730‡
600	0.746*‡	0.695‡	0.0506‡	600	0.778*‡	0.715‡	0.0625‡
700	0.786*‡	0.741‡	0.0451‡	700	0.816*‡	0.761‡	0.0548‡
800	0.829*‡	0.788‡	0.0406‡	800	0.856*‡	0.807‡	0.0485‡
900	0.872*‡	0.835‡	0.0370‡	900	0.895*‡	0.851‡	0.0437‡
1000	0.909*‡	0.875‡	0.0340‡	1000	0.933*‡	0.893‡	0.0397‡
1100	0.949*‡	0.917‡	0.0314‡	1100	0.972*‡	0.935‡	0.0364‡
1200	0.984*‡	0.955‡	0.0293‡	1200	1.01*‡	0.980‡	0.0336‡

† Uncertainties of the total thermal conductivity, k, are as follows:

10.00 Au - 90.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.
5.00 Au - 95.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.
3.00 Au - 97.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.
1.00 Au - 99.00 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 19. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (continued)†

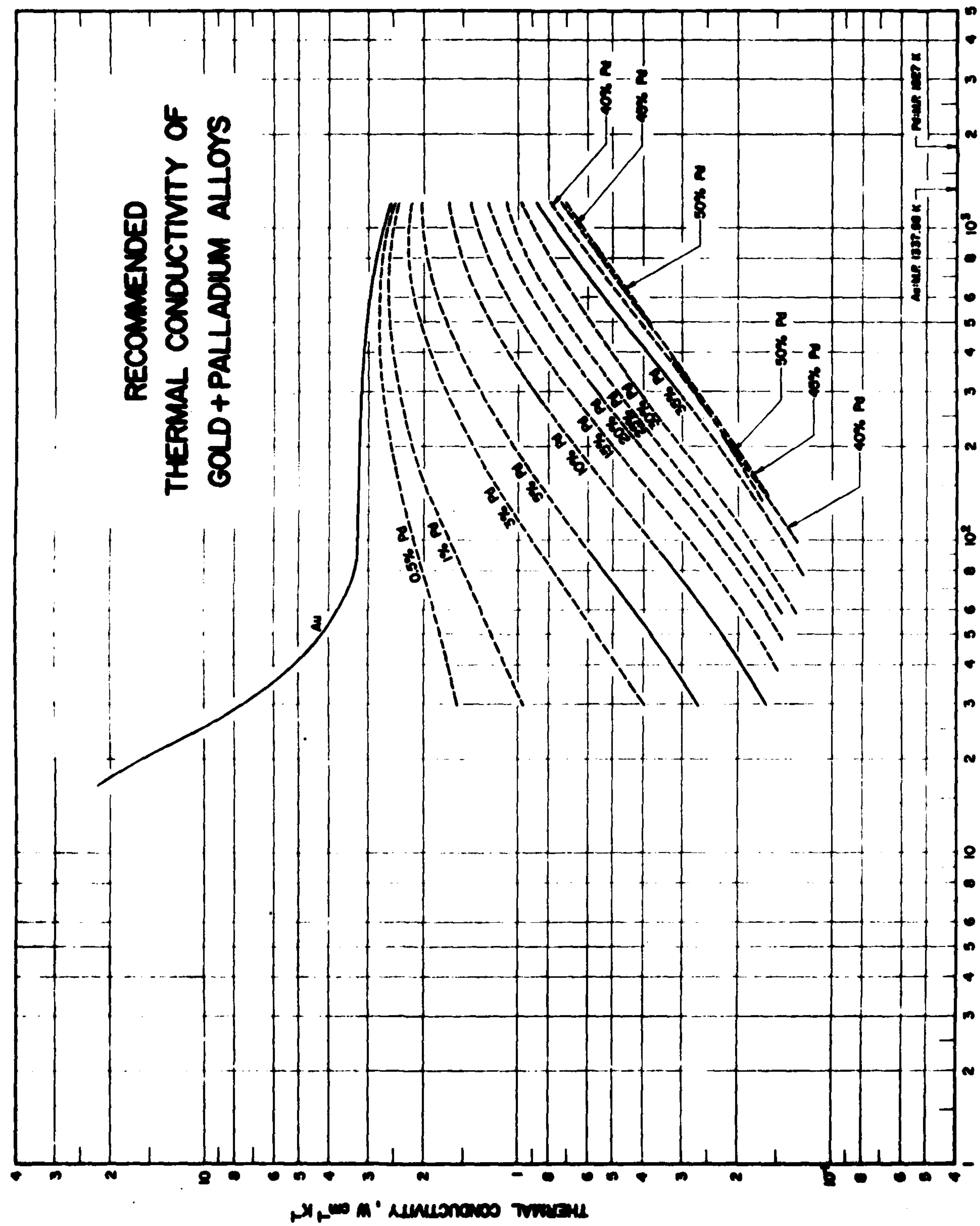
[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 0.50% (0.27 At.%) Pd: 99.50% (99.73 At.%)			
ρ_0 = 0.2600 $\mu\Omega$ cm			
T	k	k_e	k_g
4		0.376	
6		0.564	
8		0.752	
10		0.940	
15		1.41	
20		1.86	
25		1.51	
30		1.42	
40		1.16	
50		0.944	
60		0.803	
70		0.728	
80		0.686	
90		0.657	
100		0.641	
150		0.588	
200		0.563	
250		0.553	
273	0.691*‡	0.558‡	0.133‡
300	0.693*‡	0.570‡	0.123‡
350	0.703*‡	0.597‡	0.106‡
400	0.719*‡	0.623‡	0.0964‡
500	0.751*‡	0.672‡	0.0791‡
600	0.788*‡	0.721‡	0.0671‡
700	0.823*‡	0.765‡	0.0581‡
800	0.863*‡	0.811‡	0.0513‡
900	0.903*‡	0.857‡	0.0460‡
1000	0.939*‡	0.898‡	0.0416‡
1100	0.978*‡	0.940‡	0.0380‡
1200	1.02*‡	0.983‡	0.0360‡

† Uncertainties of the total thermal conductivity, k, are as follows:
0.50 Au - 99.50 Pd: ±15% at moderate temperature and above ±15% at extreme temperature.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.



RECOMMENDED
THERMAL CONDUCTIVITY OF
GOLD + PALLADIUM ALLOYS
Au
0.5% Pd
1% Pd
3% Pd
5% Pd
10% Pd
15% Pd
30% Pd
40% Pd
50% Pd
THERMAL CONDUCTIVITY, W cm^{-1} K^{-1}
TEMPERATURE, K
TPRC

FIGURE 27

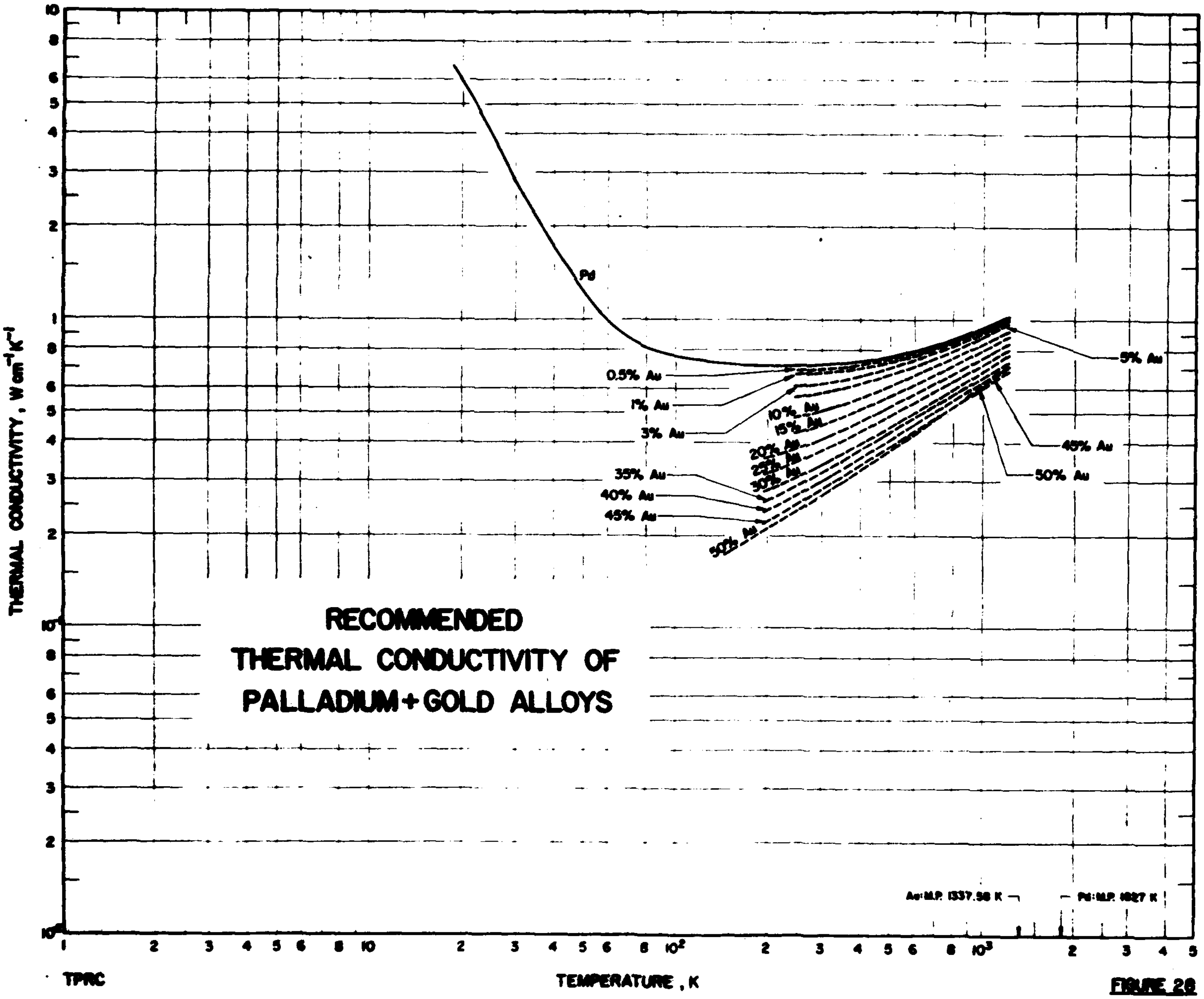
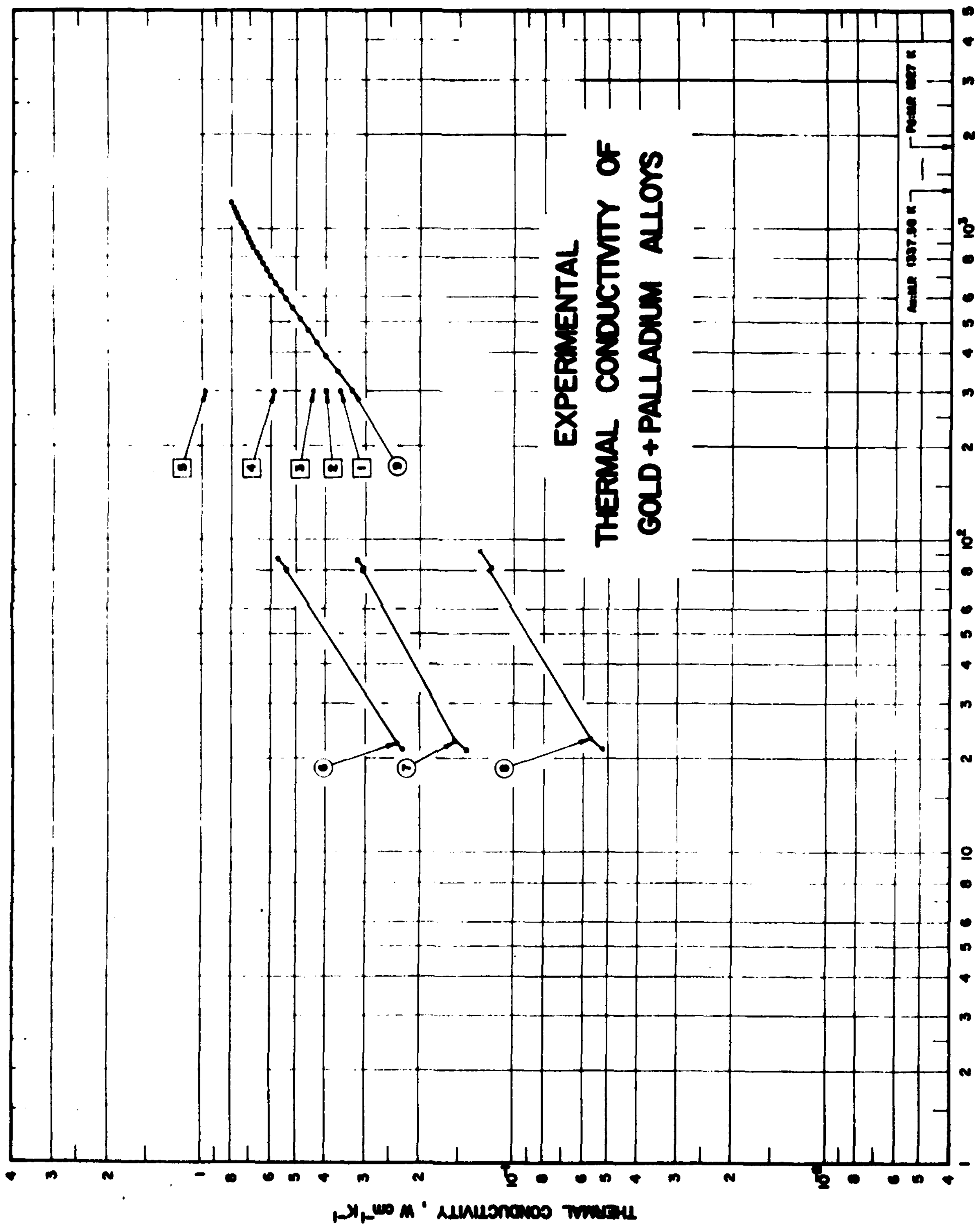

RECOMMENDED
THERMAL CONDUCTIVITY OF
PALLADIUM+GOLD ALLOYS
THERMAL CONDUCTIVITY, W cm⁻¹K⁻¹
TEMPERATURE, K
Pd
0.5% Au
1% Au
3% Au
5% Au
10% Au
15% Au
20% Au
25% Au
30% Au
35% Au
40% Au
45% Au
50% Au
Au: M.P. 1337.58 K
Pd: M.P. 1827 K
TPRC

FIGURE 28



EXPERIMENTAL
THERMAL CONDUCTIVITY OF
GOLD + PALLADIUM ALLOYS
TEMPERATURE, K
THERMAL CONDUCTIVITY, W cm⁻¹ K⁻¹
TPRC

FIGURE 22

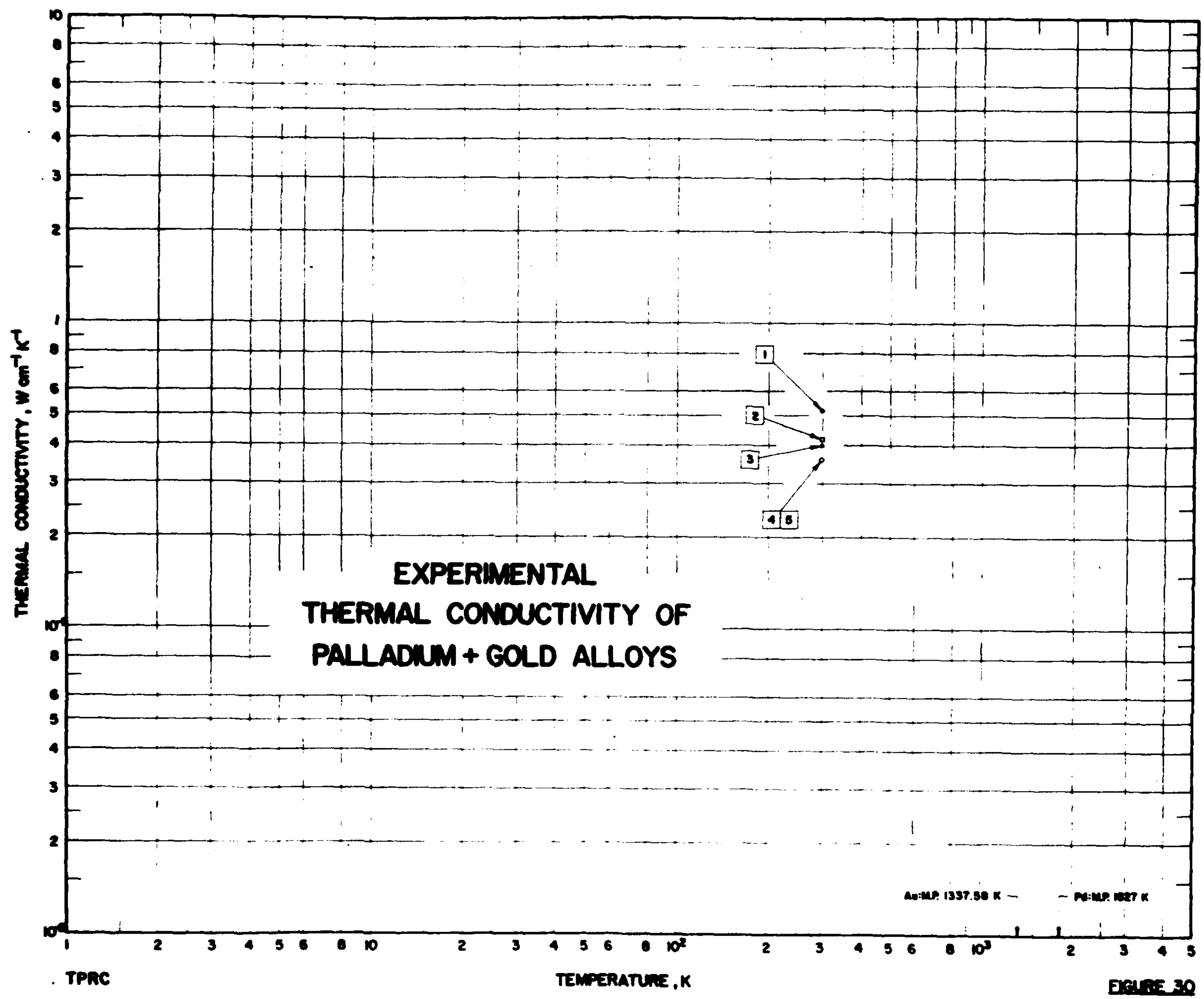

EXPERIMENTAL
THERMAL CONDUCTIVITY OF
PALLADIUM + GOLD ALLOYS
THERMAL CONDUCTIVITY, W cm⁻¹ K⁻¹
TEMPERATURE, K
Au:M.P. 1337.58 K
Pd:M.P. 1827 K
1
2
3
4
5
TPRC

FIGURE 30

TABLE 20. THERMAL CONDUCTIVITY OF GOLD - PALLADIUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Pd	Composition (continued), Specifications, and Remarks
1	93	Schulze, F.A.	1911	E	296.2		50	50	Electrical conductivity $3.74 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
2	93	Schulze, F.A.	1911	E	298.2		60	40	Electrical conductivity $4.02 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
3	93	Schulze, F.A.	1911	E	298.2		70	30	Electrical conductivity $5.45 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
4	93	Schulze, F.A.	1911	E	298.2		80	20	Electrical conductivity $7.82 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
5	93	Schulze, F.A.	1911	E	298.2		90	10	Electrical conductivity $13.27 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
6	61	Grüneisen, E. and Reddemann, H.	1934	L	21-87	22	95	5	Calculated composition; heated at 800 C for 2 hr; electrical resistivity 3.479, 3.939, and 5.44 $\mu\Omega$ cm at 22, 83, and 273 K, respectively.
7	61	Grüneisen, E. and Reddemann, H.	1934	L	21-86	23	90	10	Calculated composition; heated at 800 C for 2 hr; electrical resistivity 7.175, 7.605, and 9.10 $\mu\Omega$ cm at 22, 83, and 273 K, respectively.
8	61	Grüneisen, E. and Reddemann, H.	1934	L	21-92	24	60.1	39.9	Calculated composition; heated at 800 C for 2 hr; electrical resistivity 23.66, 24.48, and 27.1 $\mu\Omega$ cm at 22, 83, and 273, K, respectively.
9	85	Laubitz, M.J. and Van der Meer, M.P.	1968	L	300-1203	Platinel 1503	65.05	34.95	~1.2 cm in diameter and 10 cm long; supplied by Engelhard Ind.; annealed at 800 to 900 K for 60 hr; electrical resistivity ratio $\rho(273K)/\rho(4K)$ = 1.133; electrical resistivity reported as 24.3, 25.1, 25.5, 25.9, 26.4, 26.9, 27.5, 28.2, 28.9, 29.5, 30.1, 30.8, 31.5, 31.9, 33.0 $\mu\Omega$ cm at 310, 420, 485, 551, 614, 688, 755, 821, 890, 953, 1012, 1072, 1140, 1198, and 1304 K, respectively; data extracted from smooth curve.

TABLE 21. THERMAL CONDUCTIVITY OF PALLADIUM + GOLD ALLOYS — SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Au	Composition (continued), Specifications, and Remarks
1	93	Schulze, F.A.	1911	E	298.2		90	10	1 mm thick wire specimen obtained from Heracus Co.; electrical conductivity 6.65 x 10^4 Ω^{-1} cm^{-1} at 25 C.
2	93	Schulze, F.A.	1911	E	298.2		80	20	1 mm thick wire specimen obtained from Heracus Co.; electrical conductivity 5.33 x 10^4 Ω^{-1} cm^{-1} at 25 C.
3	93	Schulze, F.A.	1911	E	298.2		70	30	1 mm thick wire specimen obtained from Heracus Co.; electrical conductivity 4.72 x 10^4 Ω^{-1} cm^{-1} at 25 C.
4	93	Schulze, F.A.	1911	E	298.2		60	40	1 mm thick wire specimen obtained from Heracus Co.; electrical conductivity 3.89 x 10^4 Ω^{-1} cm^{-1} at 25 C.
5*	93	Schulze, F.A.	1911	E	298.2		50	50	1 mm thick wire specimen obtained from Heracus Co.; electrical conductivity 3.74 x 10^4 Ω^{-1} cm^{-1} at 25 C.

* Not shown in figure.

4.8. Gold-Silver Alloy System

The gold-silver alloy system forms a continuous series of solid solutions over the entire range of compositions. Possible existence of ordered structures due to the formation of AgAu intermetallic compound has been reported.

There are 39 sets of experimental data available for the thermal conductivity of this alloy system. Of the 22 data sets available for Au + Ag alloys listed in Table 23 and shown in Figure 33, 9 sets cover only a narrow temperature range from 273 to 373 K, which is the highest temperature at which data exist. Of the 17 data sets for Ag + Au alloys listed in Table 24 and shown in Figure 34, four sets likewise cover only the narrow temperature range from 273 to 373 K, which is also the highest temperature at which data exist.

Thermal conductivities of this alloy system have been reported in four papers [61, 63, 94, 95]. The measurements by Grüneisen and Reddemann [61] (Au + Ag curves 1-2 and Ag + Au curves 1-2) appear to be the most reliable, though there is some uncertainty in the compositions of their gold-rich specimens. Separation of the electronic component from their measured total thermal conductivities gives reasonable values for the lattice component, without much scatter when these k_g values are plotted against the composition. Values obtained from eq. (35) agree well with the k_g values derived from the experimental data of Grüneisen and Reddemann. The k_g values of alloys in this system are generally very small compared with the k_e values, especially at high temperatures.

The most recent measurements, by Crisp and Rungis [94] (Au + Ag curves 12-20 and Ag + Au curves 8-17), cover a wide range of composition below 300 K. Unfortunately, however, their measurements seem not to be accurate enough to give reasonable lattice thermal conductivities. Separation of the electronic component from their measured total thermal conductivities results in negative values for the lattice component for most of their specimens at 83 and 273 K. In their paper it was mentioned that the separation failed.

Early measurements by Sedström [63] (Au + Ag curves 3-11 and Ag + Au curves 3-7) in 1919 yield positive lattice thermal conductivities at 273 K, but his k_g values scatter and seem to be high.

Van Baarle et al. [95] have measured the thermal conductivity of dilute gold-rich alloys between 2 and 30 K, but they have reported only the lattice thermal conductivity values. At the present time, it is very difficult to judge the reliability of their results because total thermal conductivities are not reported and the low-temperature results of Crisp and Rungis [94] are somewhat uncertain.

Since the Au-Ag alloy system is a non-transition solid-solution alloy system, for which the calculations from eqs. (12) and (35) should be more reliable, and since the calculated results indeed match well with the reliable experimental data of Grüneisen and

Reddemann [61], the recommendations were entirely based on the calculated values. The recommended total thermal conductivity values are in agreement with the data of Grüneisen and Reddemann [61] (Au + Ag curves 1-2 and Ag-Au curves 1-2) around 80 to 90 K to within 4%, with the data of crisp and Rungis [94] (Au + Ag curves 14, 15, and 17, and Ag + Au curves 9-13, and 15) between 40 and 200 K to within 10%, and with the data of Sedström [63] (Au + Ag curves 8-11 and Ag + Au curves 4, 6, and 7) around room temperature to within 5%.

The recommended values for k, k_e, and k_g are tabulated in Table 22 for 25 alloy compositions mostly covering the temperature range from 40 K to the solidus points. These values are for well-annealed disordered alloys. For two alloys with 1% and 3% Ag, the tabulated values cover the range down to 4 K. The k_e values are given from 4 K to the solidus points for all 25 alloy compositions. The values for k are also shown in Figures 31 and 32 and their uncertainties are stated in a footnote to Table 22, in which the values of residual electrical resistivity for the alloys are also given. The uncertainties of the k_e and k_g values are indicated by their being designated as recommended, provisional, or typical values. The ranges of uncertainties of recommended, provisional, and typical values are less than ±15%, between ±15 and ±30%, and greater than ±30%, respectively.

TABLE 22. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-SILVER ALLOY SYSTEM†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 99.50% (99.09 At.%) Ag: 0.50% (0.91 At.%)				Au: 99.00% (98.19 At.%) Ag: 1.00% (1.81 At.%)				Au: 97.00% (94.66 At.%) Ag: 3.00% (5.34 At.%)				Au: 95.00% (91.23 At.%) Ag: 5.00% (8.77 At.%)			
ρ_o = 0.28 μΩcm				ρ_o = 0.530 μΩcm				ρ_o = 1.52 μΩcm				ρ_o = 2.470 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.349		4	0.219‡	0.184	0.0345‡	4	0.0869‡	0.0643	0.0226‡	4		0.0396	
6		0.524		6	0.354‡	0.277	0.0769‡	6	0.146‡	0.0964	0.0500‡	6		0.0593	
8		0.698		8	0.486‡	0.369	0.117‡	8	0.202‡	0.129	0.0729‡	8		0.0791	
10		0.873		10	0.604‡	0.461	0.143‡	10	0.250‡	0.161	0.0886‡	10		0.0989	
15		1.31		15	0.855‡	0.691	0.164‡	15	0.350‡	0.241	0.109‡	15		0.148	
20		1.75		20	1.08‡	0.922	0.160‡	20	0.435‡	0.321	0.114‡	20		0.198	
25		1.86		25	1.21‡	1.06	0.150‡	25	0.497‡	0.390	0.107‡	25		0.241	
30		2.01		30	1.33‡	1.19	0.137‡	30	0.554‡	0.454	0.0999‡	30		0.284	
40	2.19	2.07	0.117	40	1.49	1.37	0.118	40	0.657	0.571	0.0861	40	0.437	0.363	0.0740
50	2.23	2.12	0.109	50	1.60	1.50	0.104	50	0.746	0.669	0.0770	50	0.503	0.437	0.0661
60	2.28	2.18	0.100	60	1.68	1.59	0.0929	60	0.836	0.767	0.0692	60	0.567	0.507	0.0600
70	2.33	2.24	0.0922	70	1.77	1.69	0.0840	70	0.917	0.853	0.0637	70	0.628	0.573	0.0551
80	2.36	2.27	0.0849	80	1.84	1.76	0.0763	80	0.989	0.930	0.0587	80	0.686	0.634	0.0515
90	2.42	2.34	0.0785	90	1.92	1.85	0.0701	90	1.06	1.01	0.0546	90	0.747	0.694	0.0531
100	2.48	2.41	0.0728	100	2.00	1.93	0.0657	100	1.14	1.08	0.0515	100	0.798	0.753	0.0450
150	2.70	2.65	0.0528	150	2.29	2.24	0.0489	150	1.43	1.39	0.0398	150	1.05*	1.01	0.0352
200	2.80	2.76	0.0412	200	2.44	2.41	0.0388	200	1.64*	1.61	0.0326	200	1.25*	1.22	0.0292
250	2.83	2.80	0.0337	250	2.53	2.50	0.0320	250	1.80*	1.77	0.0276	250	1.41*	1.38	0.0250
273	2.85	2.82	0.0311	273	2.56	2.53	0.0297	273	1.86*	1.83	0.0258	273	1.47	1.45	0.0235
300	2.86	2.83	0.0285	300	2.59	2.56	0.0273	300	1.92*	1.90	0.0240	300	1.54	1.52	0.0219
350	2.86*	2.84	0.0247	350	2.64*	2.61	0.0238	350	2.02*	2.00	0.0212	350	1.65	1.63	0.0196
400	2.89*	2.86	0.0218	400	2.67*	2.65	0.0211	400	2.10*	2.09	0.0190	400	1.75*	1.73	0.0177
500	2.85*	2.83	0.0176	500	2.70*	2.68	0.0171	500	2.22*	2.21	0.0158	500	1.90*	1.88	0.0149
600	2.83*	2.82	0.0147	600	2.70*	2.68	0.0145	600	2.30*	2.28	0.0135	600	2.00*	1.99	0.0128
700	2.80*	2.78	0.0127	700	2.69*	2.68	0.0125	700	2.34*	2.33	0.0118	700	2.07*	2.06	0.0133
800	2.75*	2.74	0.0111	800	2.66*	2.65	0.0110	800	2.36*	2.35	0.0105	800	2.12*	2.11	0.0101
900	2.67*	2.68	0.00994	900	2.61*	2.60	0.00982	900	2.35*	2.34	0.00944	900	2.15*	2.14	0.00913
1000	2.63*	2.62	0.00896	1000	2.56*	2.55	0.00888	1000	2.33*	2.32	0.00858	1000	2.15*	2.14	0.00834
1200	2.49*	2.49	0.00749	1200	2.44*	2.43	0.00744	1200	2.27*	2.27	0.00725	1200	2.14*	2.13	0.00710
1337	2.41*	2.40	0.00670	1337	2.37*	2.36	0.00668	1336	2.22*	2.21	0.00655	1335	2.12*	2.11	0.00645

† Uncertainties of the total thermal conductivity, k, are as follows:

99.50 Au - 0.50 Ag: ±10%.
99.00 Au - 1.00 Ag: ±15% below 30 K, ±10% between 30 and 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
97.00 Au - 3.00 Ag: ±15% below 30 K, ±10% between 30 and 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
95.00 Au - 5.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 22. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-SILVER ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 90.00% (83.13 At.%) Ag: 10.00% (16.87 At.%)				Au: 85.00% (75.63 At.%) Ag: 15.00% (24.37 At.%)				Au: 80.00% (68.66 At.%) Ag: 20.00% (31.34 At.%)				Au: 75.00% (62.16 At.%) Ag: 25.00% (37.84 At.%)			
ρ_0 = 4.53 μΩ cm				ρ_0 = 6.12 μΩ cm				ρ_0 = 7.36 μΩ cm				ρ_0 = 8.24 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.0216		4		0.0160		4		0.0133		4		0.0119	
6		0.0324		6		0.0240		6		0.0199		6		0.0178	
8		0.0431		8		0.0319		8		0.0266		8		0.0237	
10		0.0539		10		0.0399		10		0.0332		10		0.0296	
15		0.0809		15		0.0599		15		0.0498		15		0.0445	
20		0.108		20		0.0798		20		0.0664		20		0.0593	
25		0.135		25		0.0989		25		0.0823		25		0.0735	
30		0.157		30		0.118		30		0.0980		30		0.0877	
40	0.262	0.205	0.0576	40	0.208	0.155	0.0531	40	0.180*	0.129	0.0509	40	0.165*	0.116	0.0490
50	0.308	0.250	0.0587	50	0.238	0.190	0.0484	50	0.205*	0.159	0.0464	50	0.188*	0.142	0.0455
60	0.344	0.296	0.0487	60	0.269	0.224	0.0447	60	0.231*	0.188	0.0427	60	0.211*	0.169	0.0419
70	0.383	0.338	0.0453	70	0.300	0.258	0.0416	70	0.257*	0.217	0.0397	70	0.234*	0.196	0.0380
80	0.421	0.379	0.0424	80	0.330	0.291	0.0389	80	0.282*	0.245	0.0372	80	0.257*	0.220	0.0365
90	0.460	0.420	0.0399	90	0.360	0.323	0.0366	90	0.308*	0.273	0.0350	90	0.280*	0.246	0.0343
100	0.497	0.460	0.0377	100	0.390*	0.355	0.0346	100	0.334*	0.301	0.0331	100	0.304*	0.271	0.0325
150	0.676	0.646	0.0299	150	0.534*	0.506	0.0275	150	0.457*	0.431	0.0264	150	0.416*	0.390	0.0259
200	0.831*	0.806	0.0250	200	0.665*	0.641	0.0232	200	0.573*	0.550	0.0223	200	0.522*	0.501	0.0219
250	0.971*	0.949	0.0217	250	0.782*	0.762	0.0202	250	0.678*	0.658	0.0194	250	0.621*	0.602	0.0192
273	1.03	1.01	0.0205	273	0.833	0.814	0.0191	273	0.723	0.704	0.0184	273	0.664	0.646	0.0181
300	1.09	1.07	0.0192	300	0.889	0.872	0.0180	300	0.775	0.757	0.0173	300	0.712	0.695	0.0171
350	1.20	1.18	0.0173	350	0.986	0.970	0.0162	350	0.864	0.848	0.0157	350	0.797	0.781	0.0155
400	1.29*	1.28	0.0158	400	1.07*	1.06	0.0149	400	0.947*	0.932	0.0144	400	0.874*	0.860	0.0143
500	1.44*	1.43	0.0135	500	1.22*	1.21	0.0128	500	1.09*	1.08	0.0124	500	1.01*	1.00	0.0123
600	1.57*	1.56	0.0118	600	1.34*	1.33	0.0112	600	1.21*	1.20	0.0110	600	1.13*	1.12	0.0109
700	1.66*	1.65	0.0105	700	1.44*	1.43	0.0101	700	1.32*	1.31	0.00987	700	1.24*	1.23	0.00968
800	1.74*	1.73	0.00946	800	1.53*	1.52	0.00913	800	1.40*	1.39	0.00898	800	1.33*	1.32	0.00895
900	1.79*	1.79	0.00863	900	1.59*	1.58	0.00836	900	1.47*	1.46	0.00825	900	1.40*	1.39	0.00823
1000	1.83*	1.82	0.00794	1000	1.64*	1.63	0.00772	1000	1.52*	1.52	0.00763	1000	1.45*	1.45	0.00763
1200	1.89*	1.88	0.00684	1200	1.72*	1.71	0.00671	1200	1.61*	1.61	0.00666	1200	1.55*	1.54	0.00668
1331	1.92*	1.91	0.00630	1327	1.77*	1.76	0.00620	1322	1.67*	1.66	0.00615	1317	1.59*	1.58	0.00620

† Uncertainties of the total thermal conductivity, k, are as follows:
90.00 Au - 10.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
85.00 Au - 15.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
80.00 Au - 20.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
75.00 Au - 25.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 22. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD–SILVER ALLOY SYSTEM (continued)[†]

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 70.00% (56.10 At.%) Ag: 30.00% (43.90 At.%)				Au: 65.00% (50.42 At.%) Ag: 35.00% (49.58 At.%)				Au: 60.00% (45.10 At.%) Ag: 40.00% (54.90 At.%)				Au: 55.00% (40.10 At.%) Ag: 45.00% (59.90 At.%)			
ρ_o = 8.77 μΩ				ρ_o = 9.0 μΩ cm				ρ_o = 8.93 μΩ cm				ρ_o = 8.66 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.0111		4		0.0109		4		0.0109		4		0.0113	
6		0.0167		6		0.0163		6		0.0164		6		0.0169	
8		0.0223		8		0.0217		8		0.0219		8		0.0226	
10		0.0279		10		0.0271		10		0.0274		10		0.0282	
15		0.0418		15		0.0407		15		0.0410		15		0.0423	
20		0.0557		20		0.0543		20		0.0547		20		0.0564	
25		0.0691		25		0.0673		25		0.0679		25		0.0701	
30		0.0825		30		0.0803		30		0.0811		30		0.0836	
40	0.159*	0.109	0.0497	40	0.156	0.106	0.0502	40	0.158*	0.107	0.0511	40	0.163*	0.110	0.0526
50	0.179*	0.134	0.0453	50	0.177	0.131	0.0457	50	0.179*	0.132	0.0466	50	0.184*	0.136	0.0479
60	0.201*	0.159	0.0417	60	0.197	0.155	0.0421	60	0.200*	0.157	0.0429	60	0.205*	0.161	0.0441
70	0.223*	0.184	0.0388	70	0.218	0.179	0.0392	70	0.221*	0.181	0.0399	70	0.227*	0.186	0.0410
80	0.244*	0.208	0.0363	80	0.240	0.203	0.0367	80	0.242*	0.205	0.0374	80	0.249*	0.211	0.0384
90	0.267*	0.232	0.0342	90	0.261	0.227	0.0345	90	0.264*	0.229	0.0352	90	0.271*	0.235	0.0362
100	0.288*	0.256	0.0324	100	0.282	0.250	0.0327	100	0.285*	0.252	0.0333	100	0.294*	0.259	0.0343
150	0.396*	0.370	0.0259	150	0.387	0.361	0.0262	150	0.391*	0.364	0.0267	150	0.402*	0.375	0.0275
200	0.497*	0.475	0.0219	200	0.486	0.464	0.0221	200	0.490*	0.468	0.0226	200	0.505*	0.481	0.0232
250	0.591*	0.571	0.0192	250	0.579	0.560	0.0194	250	0.584*	0.564	0.0198	250	0.601*	0.581	0.0203
273	0.632	0.614	0.0181	273	0.620	0.601	0.0184	273	0.624	0.606	0.0187	273	0.642	0.623	0.0193
300	0.679	0.661	0.0171	300	0.666	0.649	0.0173	300	0.671	0.653	0.0177	300	0.689	0.671	0.0182
350	0.760	0.744	0.0155	350	0.746	0.731	0.0157	350	0.752	0.736	0.0161	350	0.773	0.756	0.0165
400	0.836*	0.822	0.0143	400	0.822*	0.808	0.0145	400	0.828	0.813	0.0148	400	0.852	0.837	0.0152
500	0.969*	0.957	0.0124	500	0.956*	0.943	0.0125	500	0.964*	0.951	0.0128	500	0.992*	0.978	0.0132
600	1.09*	1.08	0.0110	600	1.07*	1.06	0.0111	600	1.08*	1.07	0.0114	600	1.12*	1.10	0.0117
700	1.19*	1.18	0.00968	700	1.18*	1.17	0.0100	700	1.19*	1.18	0.0102	700	1.22*	1.21	0.0105
800	1.28*	1.27	0.00901	800	1.26*	1.26	0.00915	800	1.28*	1.27	0.00936	800	1.31*	1.30	0.00963
900	1.36*	1.35	0.00830	900	1.34*	1.33	0.00843	900	1.35*	1.34	0.00863	900	1.39*	1.38	0.00888
1000	1.41*	1.41	0.00770	1000	1.40*	1.39	0.00783	1000	1.42*	1.41	0.00801	1000	1.45*	1.44	0.00825
1200	1.51*	1.50	0.00676	1200	1.50*	1.49	0.00687	1200	1.52*	1.51	0.00704	1100	1.51*	1.50	0.00771
1311	1.55*	1.54	0.00630	1306	1.54*	1.53	0.00650	1300	1.55*	1.54	0.00660	1295	1.59*	1.58	0.00685

[†] Uncertainties of the total thermal conductivity, k, are as follows:
70.00 Au – 30.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
65.00 Au – 35.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
60.00 Au – 40.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
55.00 Au – 45.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 22. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD–SILVER ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 50.00% (35.39 At.%) Ag: 50.00% (64.61 At.%)				Au: 45.00% (30.94 At.%) Ag: 55.00% (69.06 At.%)				Au: 40.00% (26.75 At.%) Ag: 60.00% (73.25 At.%)				Au: 35.00% (22.77 At.%) Ag: 65.00% (77.23 At.%)			
ρ_0 = 8.30 μΩcm				ρ_0 = 7.79 μΩcm				ρ_0 = 7.16 μΩcm				ρ_0 = 6.42 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.0118		4		0.0125		4		0.0136		4		0.0152	
6		0.0177		6		0.0188		6		0.0205		6		0.0228	
8		0.0235		8		0.0251		8		0.0273		8		0.0304	
10		0.0294		10		0.0314		10		0.0341		10		0.0381	
15		0.0442		15		0.0470		15		0.0512		15		0.0571	
20		0.0589		20		0.0627		20		0.0682		20		0.0761	
25		0.0732		25		0.0778		25		0.0849		25		0.0945	
30		0.0874		30		0.0989		30		0.101		30		0.113	
40	0.170*	0.115	0.0544	40	0.179*	0.122	0.0568‡	40	0.193	0.133	0.0598‡	40	0.212	0.148	0.0634‡
50	0.192*	0.142	0.0496	50	0.203*	0.151	0.0518‡	50	0.219	0.164	0.0545‡	50	0.240	0.182	0.0579‡
60	0.214*	0.169	0.0456	60	0.227*	0.179	0.0478‡	60	0.245	0.194	0.0503‡	60	0.269	0.216	0.0536‡
70	0.237*	0.194	0.0426	70	0.251*	0.206	0.0445‡	70	0.271	0.224	0.0469‡	70	0.296	0.248	0.0488‡
80	0.260*	0.220	0.0399	80	0.275*	0.234	0.0417‡	80	0.297	0.254	0.0439‡	80	0.327	0.280	0.0467‡
90	0.283*	0.246	0.0376	90	0.300*	0.261	0.0393‡	90	0.324	0.283	0.0414‡	90	0.356	0.312	0.0440‡
100	0.306*	0.271	0.0356	100	0.324*	0.287	0.0372‡	100	0.350*	0.311	0.0392‡	100	0.385*	0.344	0.0416‡
150	0.419*	0.391	0.0285	150	0.444*	0.414	0.0298‡	150	0.479*	0.448	0.0313‡	150	0.527*	0.493	0.0333‡
200	0.526*	0.502	0.0241	200	0.557*	0.532	0.0252‡	200	0.600*	0.573	0.0265‡	200	0.658*	0.630	0.0282‡
250	0.626*	0.605	0.0211	250	0.662*	0.640	0.0220‡	250	0.712*	0.689	0.0232‡	250	0.780*	0.756	0.0246‡
273	0.670	0.650	0.0200	273	0.706	0.687	0.0209‡	273	0.760*	0.738	0.0220‡	273	0.833*	0.810	0.0233‡
300	0.719	0.701	0.0189	300	0.760	0.740	0.0197‡	300	0.816*	0.795	0.0207‡	300	0.892*	0.870	0.0220‡
350	0.806	0.789	0.0171	350	0.851	0.833	0.0179‡	350	0.913*	0.894	0.0188‡	350	0.996*	0.976	0.0200‡
400	0.888*	0.872	0.0158	400	0.936*	0.920	0.0164‡	400	1.00*	0.987	0.0173‡	400	1.09*	1.07	0.0183‡
500	1.03*	1.02	0.0136	500	1.09*	1.07	0.0142‡	500	1.16*	1.15	0.0149‡	500	1.26*	1.24	0.0158‡
600	1.16*	1.15	0.0121	600	1.22*	1.21	0.0126‡	600	1.30*	1.29	0.0132‡	600	1.40*	1.39	0.0140‡
700	1.27*	1.26	0.0109	700	1.34*	1.32	0.0114‡	700	1.42*	1.41	0.0119‡	700	1.52*	1.51	0.0126‡
800	1.36*	1.35	0.00996	800	1.43*	1.42	0.0104‡	800	1.52*	1.51	0.0109‡	800	1.62*	1.61	0.0114‡
900	1.44*	1.43	0.00918	900	1.51*	1.50	0.00955‡	900	1.60*	1.59	0.00999‡	900	1.71*	1.70	0.0105‡
1000	1.51*	1.50	0.00853	1000	1.58*	1.57	0.00887‡	1000	1.67*	1.66	0.00927‡	1000	1.78*	1.77	0.00974‡
1100	1.59*	1.58	0.00797	1100	1.63*	1.62	0.00828‡	1100	1.73*	1.72	0.00865‡	1100	1.84*	1.83	0.00906‡
[illegible]	1.65*	1.64	0.00710	1284	1.72*	1.71	0.00740‡	1278	1.82*	1.81	0.00775‡	1273	1.93*	1.92	0.00820‡

† Uncertainties of the total thermal conductivity, k, are as follows:
50.00 Au – 50.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
45.00 Au – 55.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
40.00 Au – 60.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
35.00 Au – 65.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 22. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-SILVER ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 30.00% (19.01 At.%) Ag: 70.00% (80.99 At.%)				Au: 25.00% (15.44 At.%) Ag: 75.00% (84.56 At.%)				Au: 20.00% (12.04 At.%) Ag: 80.00% (87.96 At.%)				Au: 15.00% (8.81 At.%) Ag: 85.00% (91.19 At.%)			
ρ_0 = 5.60 μΩcm				ρ_0 = 4.75 μΩcm				m ρ_0 = 3.86 μΩcm				ρ_0 = 2.94 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.0175		4		0.0206		4		0.0253		4		0.0332	
6		0.0262		6		0.0309		6		0.0380		6		0.0499	
8		0.0349		8		0.0411		8		0.0506		8		0.0665	
10		0.0436		10		0.0514		10		0.0633		10		0.0831	
15		0.0654		15		0.0771		15		0.0949		15		0.125	
20		0.0873		20		0.103		20		0.127		20		0.166	
25		0.108		25		0.127		25		0.157		25		0.206	
30		0.129		30		0.152		30		0.187		30		0.244	
40	0.237*	0.169	0.0679‡	40	0.272*	0.198	0.0736‡	40	0.326	0.245	0.0809‡	40	0.408	0.317	0.0909‡
50	0.270*	0.208	0.0621‡	50	0.311*	0.244	0.0674‡	50	0.373	0.299	0.0744‡	50	0.469	0.385	0.0839‡
60	0.303*	0.245	0.0574‡	60	0.348*	0.286	0.0624‡	60	0.418	0.349	0.0689‡	60	0.524	0.446	0.0779‡
70	0.335*	0.282	0.0535‡	70	0.387*	0.328	0.0582‡	70	0.464	0.400	0.0643‡	70	0.580	0.508	0.0728‡
80	0.368*	0.318	0.0502‡	80	0.424*	0.370	0.0546‡	80	0.509	0.448	0.0603‡	80	0.635	0.567	0.0683‡
90	0.401*	0.354	0.0473‡	90	0.462*	0.411	0.0514‡	90	0.553	0.496	0.0569‡	90	0.691	0.626	0.0644‡
100	0.434*	0.389	0.0447‡	100	0.500*	0.451	0.0487‡	100	0.597	0.543	0.0538‡	100	0.744	0.683	0.0609‡
150	0.592*	0.556	0.0358‡	150	0.678*	0.640	0.0389‡	150	0.805	0.762	0.0429‡	150	0.990	0.942	0.0484‡
200	0.737*	0.707	0.0302‡	200	0.841*	0.808	0.0328‡	200	0.987*	0.951	0.0361‡	200	1.20*	1.16	0.0406‡
250	0.871*	0.844	0.0263‡	250	0.988*	0.960	0.0285‡	250	1.15*	1.12	0.0313‡	250	1.38*	1.35	0.0351‡
273	0.928	0.903	0.0249‡	273	1.05*	1.02	0.0270‡	273	1.22	1.19	0.0296‡	273	1.46*	1.43	0.0331‡
300	0.993	0.969	0.0235‡	300	1.12*	1.09	0.0254‡	300	1.29	1.26	0.0278‡	300	1.54*	1.51	0.0311‡
350	1.10	1.08	0.0213‡	350	1.24	1.21	0.0230‡	350	1.42	1.39	0.0251‡	350	1.68*	1.65	0.0279‡
400	1.20*	1.18	0.0195‡	400	1.35*	1.33	0.0210‡	400	1.54*	1.51	0.0229‡	400	1.80*	1.78	0.0254‡
500	1.38*	1.36	0.0168‡	500	1.53*	1.51	0.0181‡	500	1.73*	1.71	0.0196‡	500	2.01*	1.99	0.0216‡
600	1.53*	1.51	0.0148‡	600	1.68*	1.67	0.0159‡	600	1.89*	1.87	0.0172‡	600	2.17*	2.15	0.0188‡
700	1.65*	1.64	0.0133‡	700	1.81*	1.80	0.0142‡	700	2.02*	2.00	0.0154‡	700	2.29*	2.27	0.0167‡
800	1.76*	1.74	0.0121‡	800	1.91*	1.90	0.0129‡	800	2.12*	2.10	0.0139‡	800	2.38*	2.36	0.0151‡
900	1.83*	1.82	0.0111‡	900	1.99*	1.98	0.0118‡	900	2.19*	2.18	0.0127‡	900	2.45*	2.44	0.0137‡
1000	1.91*	1.90	0.0103‡	1000	2.06*	2.05	0.0109‡	1000	2.26*	2.24	0.0117‡	1000	2.50*	2.49	0.0126‡
1100	1.97*	1.96	0.00958‡	1100	2.12*	2.11	0.0101‡	1100	2.31*	2.30	0.0108‡	1100	2.54*	2.53	0.0116‡
1267	2.06*	2.05	0.00860‡	1261	2.20*	2.19	0.00920‡	1256	2.38*	2.37	0.00980‡	1251	2.59*	2.58	0.0105‡

† Uncertainties of the total thermal conductivity, k, are as follows:
30.00 Au - 70.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
25.00 Au - 75.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
20.00 Au - 80.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
15.00 Au - 85.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 22. RECOMMENDED THERMAL CONDUCTIVITY OF GOLD-SILVER ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 10.00% (5.74 At.%) Ag: 90.00% (94.26 At.%)				Au: 5.00% (2.80 At.%) Ag: 95.00% (97.20 At.%)				Au: 3.00% (1.67 At.%) Ag: 97.00% (98.33 At.%)				Au: 1.00% (0.55 At.%) Ag: 99.00% (99.45 At.%)			
ρ_o = 1.97 μΩ cm				ρ_o = 0.99 μΩ cm				ρ_o = 0.59 μΩ cm				ρ_o = 0.190 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4		0.0496		4		0.0987		4		0.166		4		0.514	
6		0.0744		6		0.148		6		0.248		6		0.771	
8		0.0992		8		0.197		8		0.331		8		1.03	
10		0.124		10		0.247		10		0.414		10		1.29	
15		0.186		15		0.370		15		0.621		15		1.93	
20		0.248		20		0.494		20		0.828		20		2.57	
25		0.305		25		0.596		25		1.00		25		2.90	
30		0.363		30		0.705		30		1.15		30		3.21	
40	0.571	0.465	0.106‡	40	1.02	0.873	0.145‡	40	1.53	1.36	0.170‡	40	3.49	3.28	0.211‡
50	0.655	0.557	0.0981‡	50	1.14	1.01	0.132‡	50	1.65	1.50	0.154‡	50	3.31	3.12	0.191‡
60	0.726	0.635	0.0914‡	60	1.23	1.11	0.121‡	60	1.73	1.59	0.140‡	60	3.10	2.93	0.174‡
70	0.801	0.715	0.0855‡	70	1.32	1.21	0.112‡	70	1.84	1.71	0.129‡	70	3.10	2.94	0.159‡
80	0.872	0.782	0.0903‡	80	1.42	1.32	0.104‡	80	1.95	1.83	0.119‡	80	3.11	2.96	0.148‡
90	0.944	0.869	0.0757‡	90	1.52	1.43	0.0962‡	90	2.05	1.94	0.111‡	90	3.18	3.04	0.137‡
100	1.01	0.940	0.0716‡	100	1.62	1.53	0.0908‡	100	2.14	2.04	0.105‡	100	3.26	3.13	0.128‡
150	1.32	1.26	0.0566‡	150	2.00	1.92	0.0706‡	150	2.53	2.45	0.0799‡	150	3.50	3.41	0.0941‡
200	1.56	1.51	0.0471‡	200	2.27	2.21	0.0577‡	200	2.79	2.73	0.0643‡	200	3.67	3.59	0.0737‡
250	1.76	1.72	0.0404‡	250	2.49	2.44	0.0488‡	250	2.98	2.93	0.0538‡	250	3.77	3.71	0.0605‡
273	1.84	1.80	0.0390‡	273	2.57	2.52	0.0456‡	273	3.05	3.00	0.0500‡	273	3.77	3.71	0.0558‡
300	1.93	1.90	0.0355‡	300	2.64	2.60	0.0423‡	300	3.11	3.06	0.0462‡	300	3.81	3.75	0.0512‡
350	2.06	2.03	0.0318‡	350	2.77	2.74	0.0374‡	350	3.21	3.17	0.0405‡	350	3.84*	3.79	0.0444‡
400	2.21*	2.18	0.0287‡	400	2.88*	2.85	0.0335‡	400	3.29*	3.26	0.0360‡	400	3.87*	3.83	0.0391‡
500	2.40*	2.38	0.0248‡	500	3.03*	3.00	0.0277‡	500	3.39*	3.36	0.0295‡	500	3.87*	3.84	0.0316‡
600	2.55*	2.53	0.0209‡	600	3.13*	3.11	0.0237‡	600	3.45*	3.43	0.0250‡	600	3.85*	3.82	0.0265‡
700	2.66*	2.64	0.0185‡	700	3.19*	3.17	0.0206‡	700	3.47*	3.45	0.0217‡	700	3.82*	3.80	0.0229‡
800	2.73*	2.72	0.0165‡	800	3.22*	3.20	0.0183‡	800	3.48*	3.46	0.0192‡	800	3.79*	3.77	0.0201‡
900	2.77*	2.76	0.0150‡	900	3.27*	3.21	0.0165‡	900	3.45*	3.44	0.0171‡	900	3.72*	3.70	0.0179‡
1000	2.80*	2.79	0.0137‡	1000	3.22*	3.20	0.0149‡	1000	3.41*	3.40	0.0155‡	1000	3.65*	3.64	0.0161‡
1100	2.83*	2.82	0.0126‡	1100	3.20*	3.19	0.0137‡	1100	3.38*	3.36	0.0142‡	1100	3.58*	3.56	0.0147‡
1245	2.87*	2.86	0.0114‡	1240	3.18*	3.17	0.0123‡	1238	3.32*	3.31	0.0126‡	1236	3.50*	3.49	0.0132‡

† Uncertainties of the total thermal conductivity, k, are as follows:
10.00 Au - 90.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
5.00 Au - 95.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
3.00 Au - 97.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.
1.00 Au - 99.00 Ag: ±10% below 273 K, ±7% between 273 and 500 K, and ±10% above 500 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 22. RECOMMENDED THERMAL CONDUCTIVITY OF *GOLD-SILVER ALLOY SYSTEM* (*continued*)†

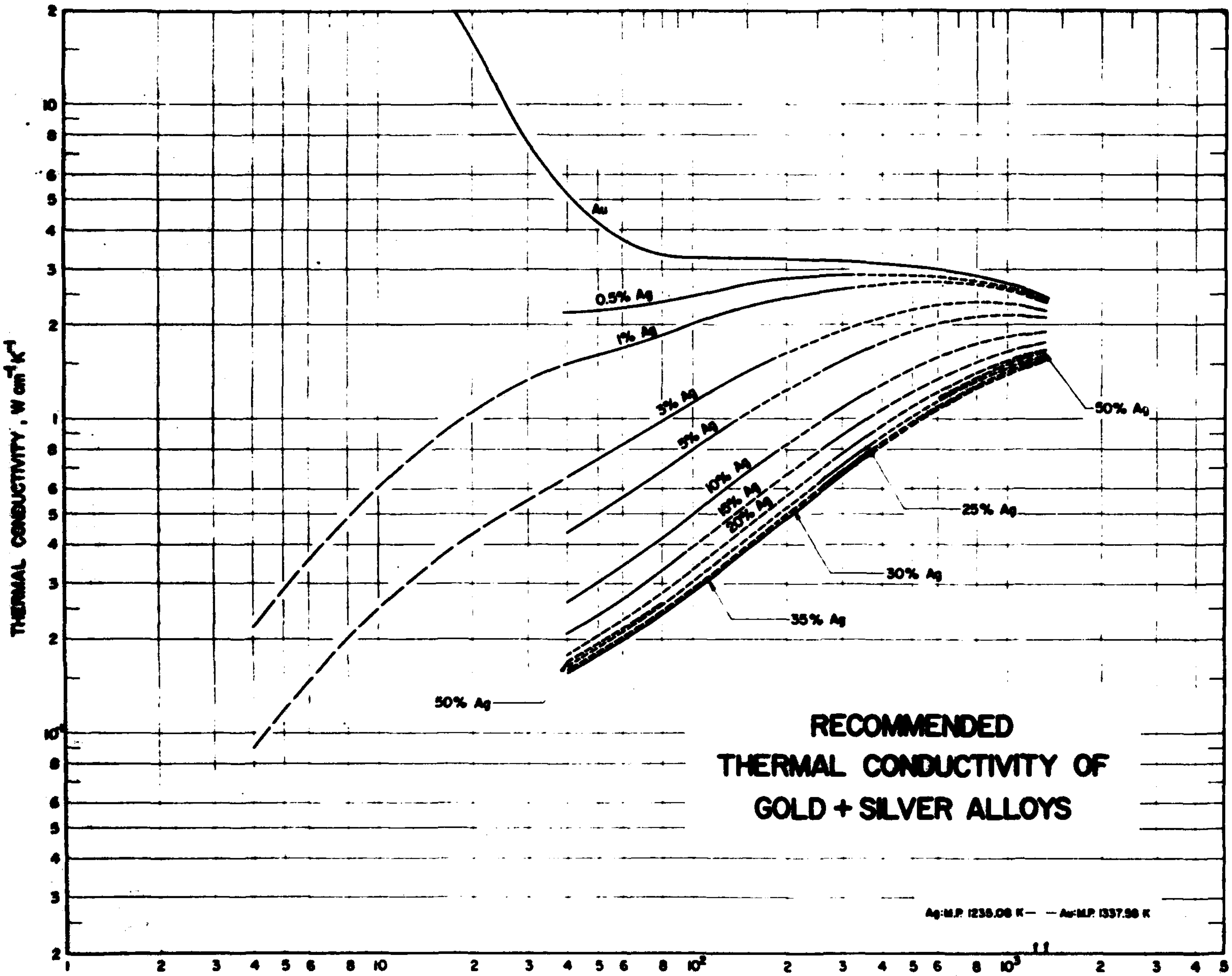
[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Au: 0.50% (0.28 At.%) Ag: 99.50% (99.72 At.%)						
ρ_0 = 0.0800 $\mu\Omega$cm						
T	k	k_e	k_g			
4		1.22				
6		1.83				
8		2.44				
10		3.05				
15		4.58				
20		6.11				
25		6.66				
30		6.20				
40	5.18	4.93	0.245§			
50	4.40	4.18	0.219§			
60	3.86	3.66	0.196§			
70	3.73	3.55	0.175§			
80	3.72	3.56	0.158§			
90	3.74	3.59	0.146§			
100	3.78	3.64	0.137§			
150	3.90	3.80	0.0989§			
200	3.95	3.88	0.0708§			
250	4.02	3.96	0.0625§			
273	4.01	3.96	0.0579§			
300	4.03	3.98	0.0527§			
350	4.03	3.99	0.0455§			
400	4.02*	3.98	0.0400§			
500	4.01*	3.98	0.0323§			
600	3.97*	3.94	0.0270§			
700	3.92*	3.90	0.0232§			
800	3.87*	3.85	0.0203§			
900	3.79*	3.77	0.0181§			
1000	3.71*	3.69	0.0163§			
1100	3.64*	3.62	0.0148§			
1235	3.55*	3.54	0.0133§			

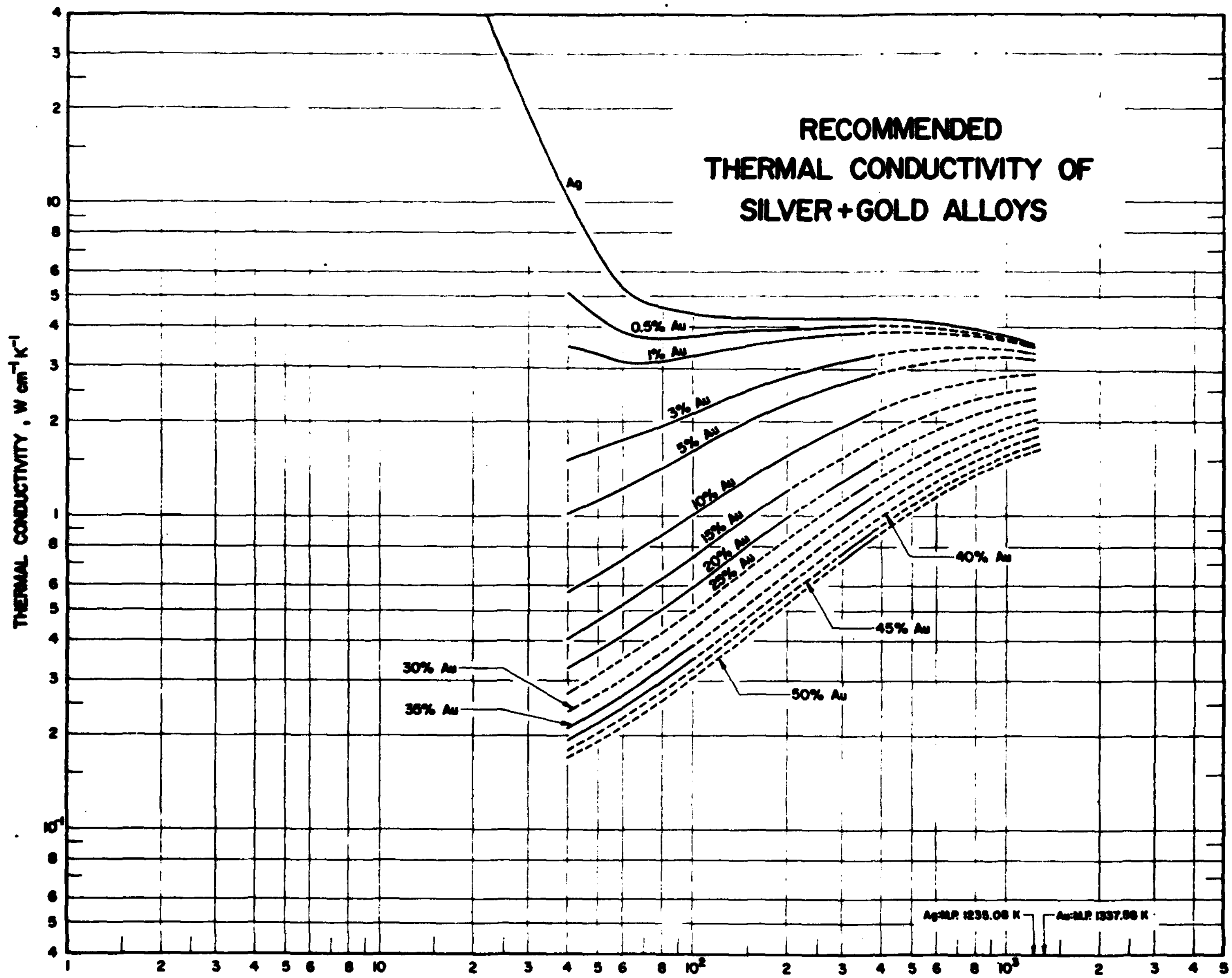
† Uncertainties of the total thermal conductivity, k, are as follows:
0.50 Au - 99.50 Ag: ±10%.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.



TPRC TEMPERATURE, K FIGURE 31



TPRC

FIGURE 32

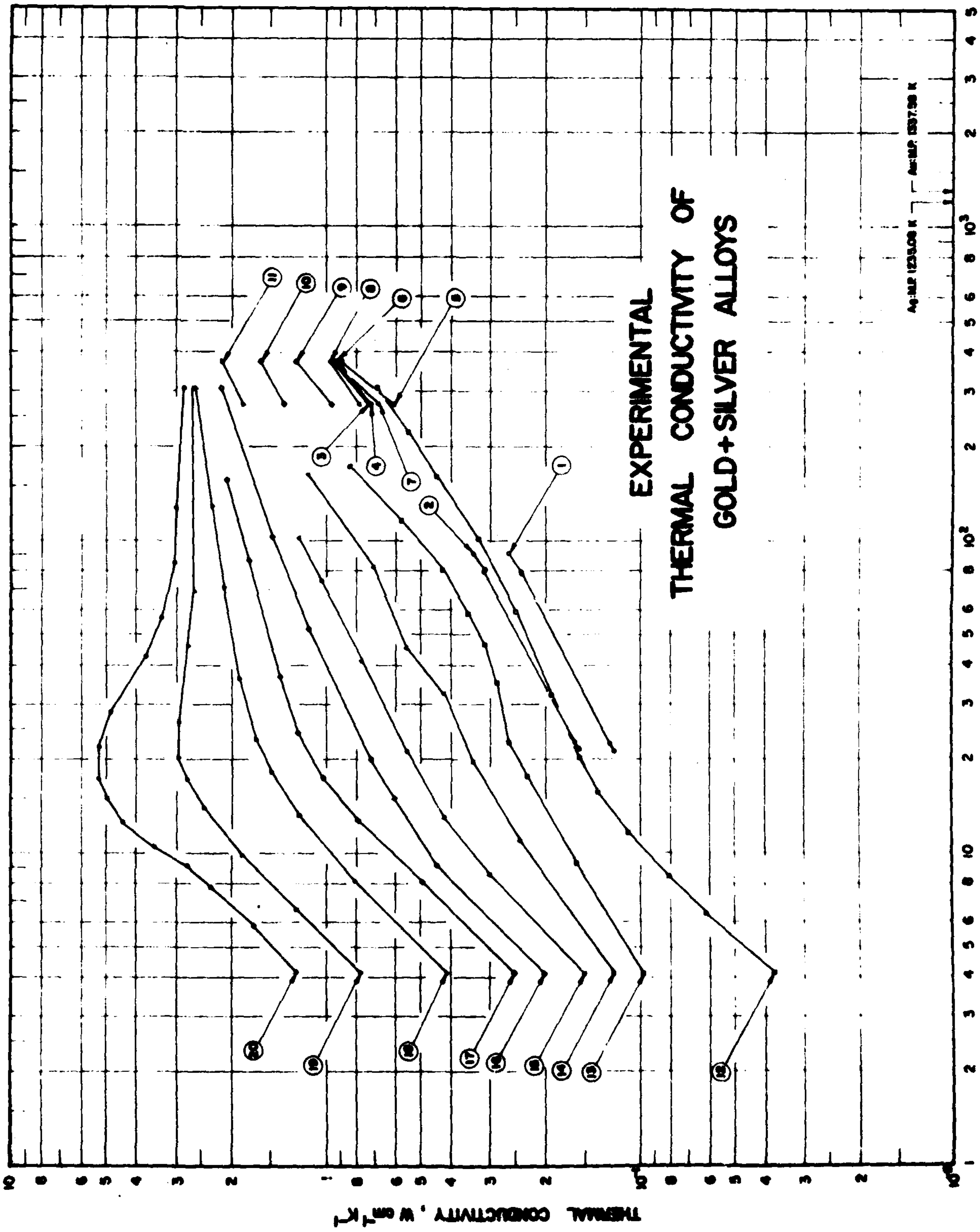
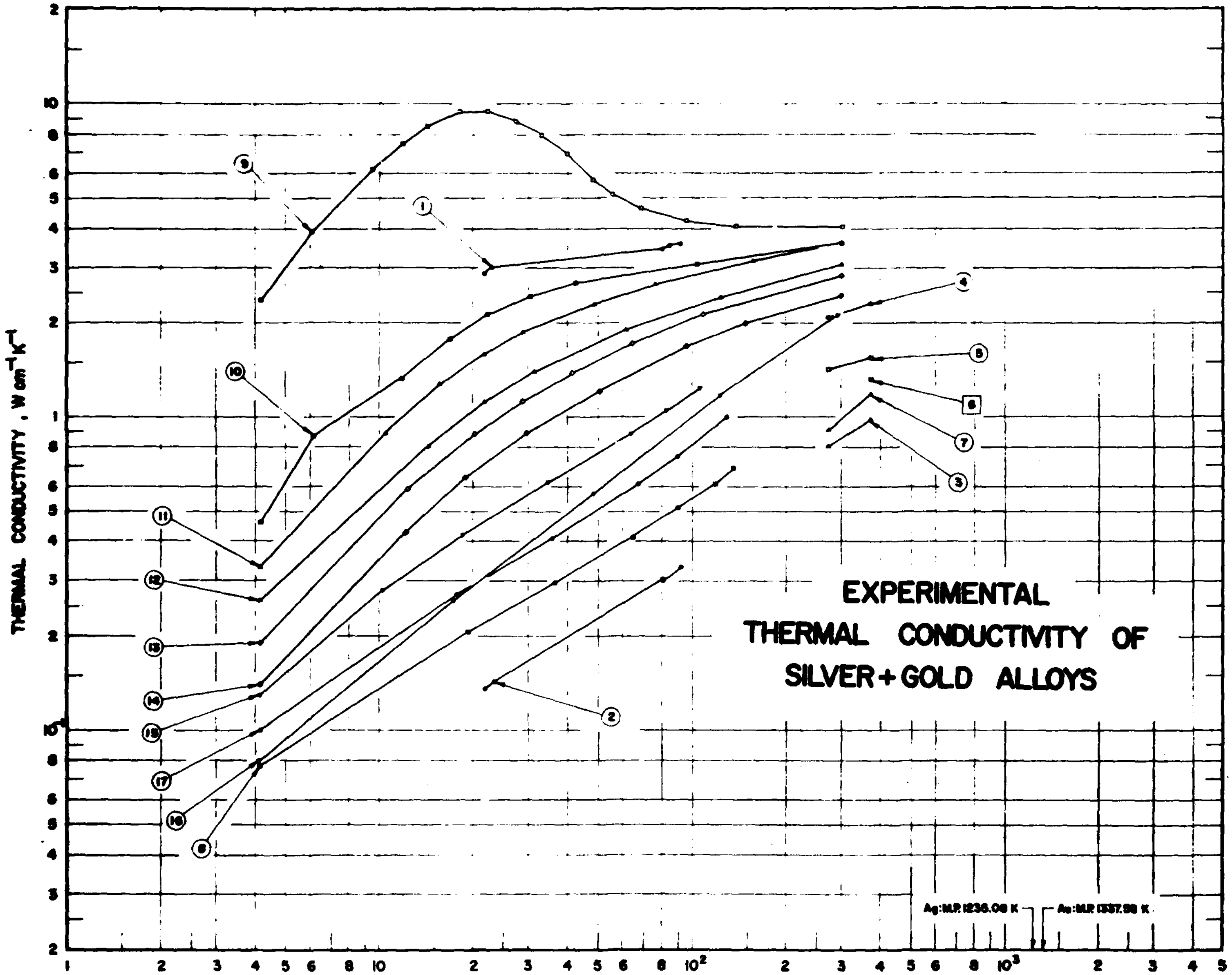

EXPERIMENTAL
THERMAL CONDUCTIVITY OF
GOLD+SILVER ALLOYS
THERMAL CONDUCTIVITY, W cm⁻¹ K⁻¹
TEMPERATURE, K
Ag: M.P. 1235.08 K
Au: M.P. 1337.58 K
TPRC

FIGURE 33



TPRC

FIGURE 34

TABLE 23. THERMAL CONDUCTIVITY OF GOLD + SILVER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Ag	Composition (continued), Specifications, and Remarks
1	61	Grüneisen, E. and Reddemann, H.	1934	L	21-91	6	64.6	35.4	Calculated composition; single crystal; electrical resistivity 8.85, 9.32, and 10.8 $\mu\Omega$ cm at 22, 83, and 273 K, respectively.
2	61	Grüneisen, E. and Reddemann, H.	1934	L	22-92	7	84.5	15.5	Calculated composition; single crystal; electrical resistivity 6.69, 7.16, and 8.69 $\mu\Omega$ cm at 22, 83, and 273 K, respectively.
3	63	Sedström, E.	1919	T	273,373		54.62	45.38	Calculated composition; specimen rolled and drawn to 1 mm thick; heated 0.5 hr at temperature near the melting point; electrical conductivity 9.1 and 8.4 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
4	63	Sedström, E.	1919	T	273,373		60.32	39.68	Similar to the above specimen except electrical conductivity 9.1 and 8.5 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
5	63	Sedström, E.	1919	T	273,373		65.46	34.54	Similar to the above specimen except electrical conductivity 7.2 and 7.2 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
6	63	Sedström, E.	1919	T	273,373		69.17	30.83	Similar to the above specimen except electrical conductivity 8.9 and 8.4 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
7	63	Sedström, E.	1919	T	273,373		73.19	26.81	Similar to the above specimen except electrical conductivity 9.1 and 8.5 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
8	63	Sedström, E.	1919	T	273,373		81.23	18.77	Similar to the above specimen except electrical conductivity 10.2 and 9.6 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
9	63	Sedström, E.	1919	T	273,373		88.82	11.18	Similar to the above specimen except electrical conductivity 13.2 and 12.4 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
10	63	Sedström, E.	1919	T	273,373		93.84	6.16	Similar to the above specimen except electrical conductivity 18.1 and 15.9 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
11	63	Sedström, E.	1919	T	273,373		97.26	2.74	Similar to the above specimen except electrical conductivity 25.1 and 22.0 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 0 and 100 C, respectively.
12	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-307			35.39	Calculated composition from atomic percent; specimen purchased in three batches from Cambridge Metals Research Ltd., England, prepared from 99.999 and 99.9999 Au and 99.9999 Ag; about 0.5 to 1 mm in diameter and about 1 to 5 cm long; drawn down, etched, washed in distilled water and alcohol, dried and sealed into quartz capsules with 1/3 atmosphere of oxygen and then annealed for 72 hr at 900 C.
13	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-173			12.7	Similar to the above specimen except the electrical resistivity reported as 6.038 and 8.107 $\mu\Omega$ cm at 0 and 273 K, respectively.
14	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-165			4.43	Similar to the above specimen except the electrical resistivity reported as 2.603 and 4.695 $\mu\Omega$ cm at 0 and 273 K, respectively.
15	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-100			2.29	Similar to the above specimen except the electrical resistivity reported as 1.404 and 3.517 $\mu\Omega$ cm at 0 and 273 K, respectively.
16	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-307			1.33	Similar to the above specimen except the electrical resistivity reported as 0.855 and 2.991 $\mu\Omega$ cm at 0 and 273 K, respectively.
17	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-156			1.06	Similar to the above specimen except the residual electrical resistivity reported as 0.670 $\mu\Omega$ cm.
19	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-307			0.47	Similar to the above specimen except the electrical resistivity reported as 0.370 and 2.421 $\mu\Omega$ cm at 0 and 273 K, respectively.

TABLE 23. THERMAL CONDUCTIVITY OF GOLD + SILVER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Ag	Composition (continued), Specifications, and Remarks
19	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-307			0.203	Similar to the above specimen except the electrical resistivity reported as 0.135 and 2.209 $\mu\Omega$ cm at 0 and 273 K, respectively.
20	94	Crisp, R.S. and Rungis, J.	1970	L	4.2-307			0.082	Similar to the above specimen except the electrical resistivity reported as 0.053 and 2.128 $\mu\Omega$ cm at 0 and 273 K, respectively.
21*	172	Kapoor, A., Rowlands, J.A., and Woods, S.B.	1974	L	0.65-4.0		94.26	5.74	Calculated composition (10 a/o Ag); 4 mm^2 in cross section and 10 cm long; prepared by induction melting 99.999 pure metals in argon, resulted ingot rolled to size; cold-worked; residual electrical resistivity 2.90 $\mu\Omega$ cm.
22*	172	Kapoor, A., et al.	1974	L	0.69-4.0				The above specimen annealed in vacuum at 1000 K for 12 hr; residual electrical resistivity 2.71 $\mu\Omega$ cm.

* Not shown in figure.

TABLE 24. THERMAL CONDUCTIVITY OF SILVER + GOLD ALLOYS — SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Composition (weight percent) Au	Composition (continued), Specifications, and Remarks
1	61	Grüneisen, E. and Reddemann, H.	1934	L	22-92	4	99.3	0.7	Calculated composition; wire specimen; electrical resistivity 0.163, 0.473, and 1.63 μΩ cm at 22, 83, and 273 K, respectively.
2	61	Grüneisen, E. and Reddemann, H.	1934	L	22-92	5	62.2	37.8	Calculated composition; single crystal; wire specimen; electrical resistivity 6.87, 7.25, and 8.57 μΩ cm at 22, 83, and 273 K, respectively.
3	63	Sedström, E.	1919	T	273, 373		55.84	44.16	Calculated composition: wire specimen 1 mm in diameter; rolled and drawn; annealed at close to melting point for 0.5 hr; electrical conductivity 10.3 and 9.7 x 10^4 Ω^{-1} cm^{-1} at 0 and 100 C, respectively.
4	63	Sedström, E.	1919	T	273, 373		91.22	8.78	Similar to the above specimen; electrical conductivity 29.3 and 24.2 x 10^4 Ω^{-1} cm^{-1} at 0 and 100 C, respectively.
5	63	Sedström, E.	1919	T	273, 373		80.74	19.26	Similar to the above specimen except electrical conductivity 19.5 and 16.0 x 10^4 Ω^{-1} cm^{-1} at 0 and 100 C, respectively.
6	63	Sedström, E.	1919	T	273.2		76.34	23.66	Similar to the above specimen except electrical conductivity 14.7 and 13.5 x 10^4 Ω^{-1} cm^{-1} at 0 and 100 C, respectively.
7	63	Sedström, E.	1919	T	273, 373		68.63	31.37	Similar to the above specimen except electrical conductivity 12.5 and 11.5 x 10^4 Ω^{-1} cm^{-1} at 0 and 100 C, respectively.
8	94	Crisp, R.S. and Rungis, J.	1970	L	4.2-136			40.31	Calculated composition from atomic percent; specimen purchased in three batches from Cambridge Metals Research Ltd., England; prepared from 99.9999 Ag and 99.999 and 99.9999 Au; about 0.5 to 1 mm in diameter and about 1 to 5 cm long; drawn down, etched, washed in distilled water and alcohol, dried and sealed into quartz capsules with 1/3 atmosphere of oxygen and then annealed for 72 hr at 900 C; electrical resistivity reported as 7.084 and 8.874 μΩ cm at 0 and 273 K, respectively.
9	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-136			0.164	Similar to the above specimen except the electrical resistivity reported as 0.033 and 1.532 μΩ cm at 0 and 273 K, respectively.
10	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-300			1.25	Similar to the above specimen except the electrical resistivity reported as 0.249 and 1.758 μΩ cm at 0 and 273 K, respectively.
11	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-300			1.43	Similar to the above specimen except the electrical resistivity reported as 0.285 and 1.788 μΩ cm at 0 and 273 K, respectively.
12	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-300			2.47	Similar to the above specimen except the electrical resistivity reported as 0.493 and 2.052 μΩ cm at 0 and 273 K, respectively.
13	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-300			2.97	Similar to the above specimen except the electrical resistivity reported as 0.593 and 2.126 μΩ cm at 0 and 273 K, respectively.
14	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-300			3.95	Similar to the above specimen except the electrical resistivity reported as 0.768 and 2.507 μΩ cm at 0 and 273 K, respectively.
15	94	Crisp, R.S. and Rungis, J.	1970	L	4.2-106			9.27	Similar to the above specimen except the electrical resistivity reported as 1.813 and 3.406 μΩ cm at 0 and 273 K, respectively.
16	94	Crisp, R.S. and Rungis, J.	1970	L	4.2-294			9.94	Similar to the above specimen except the electrical resistivity reported as 1.923 and 3.581 μΩ cm at 0 and 273 K, respectively.
17	94	Crisp, R.S. and Rungis, J.	1970	L	4.1-129			16.87	Similar to the above specimen except the electrical resistivity reported as 3.303 and 4.958 μΩ cm at 0 and 273 K, respectively.

4.9. Iron-Nickel Alloy System

The iron-nickel alloy system does not form a continuous series of solid solutions. The maximum solid solubility of nickel in iron is 6.81% (6.5 At.%) at 618 K and the solubility decreases at higher and lower temperatures. For nickel-rich alloys the solubility of iron in nickel is uncertain due to the possible formation of $FeNi_3$ ordered structures. The solid solubility of iron in nickel around room temperature may be below 3%.

There are 98 sets of experimental data available for the thermal conductivity of this alloy system. However, of the 63 data sets available for Fe + Ni alloys listed in Table 26 and shown in Figure 37, 34 sets are merely single data points, and of the 35 data sets for Ni + Fe alloys listed in Table 27 and shown in Figure 38, five sets are single data points and 21 sets are for temperatures below 4.5 K.

For Fe + Ni alloys, no specimen containing less than 3% Ni was measured below 100 K. The conductivity-composition curve for 300 K was constructed based on the data of Powell and Hickman [96] (Fe + Ni curves 3 and 4), Kohlhaas and Kierspe [97] (Fe + Ni curves 30, 31, and 63), and Ingersoll, et al. [98] (Fe + Ni curves 7-16). The electronic thermal conductivities were calculated from eq. (12) except for those alloys with nickel-content ≥20% at temperatures above 300 K where the k_e calculations appear to be unreliable. The k_e values at 300 K were also plotted in the conductivity-composition graph. The differences between k and k_e were taken as k_g, which were extrapolated to lower and higher temperatures on the basis of appropriate theoretical temperature dependences. The total thermal conductivity for each composition was then obtained by adding k_g to the calculated k_e except for those alloys containing more than 20% nickel at temperatures above 300 K, where k's were derived from the experimental data and then k_e's were obtained by subtracting k_g from k. The resulting values are in agreement with the data of Chari and de Nobel [99] (Fe + Ni curves 1, 33, and 34) and Kohlhaas and Kierspe [97] (Fe + Ni curves 30 and 31) at low temperatures to within 10%, and with the data of Bäcklund [101] (Fe + Ni curves 24 and 25) and Watson and Robinson [102] (Fe + Ni curves 19, 26, 28, 29, and 62) at higher temperatures to within 12%. In the process of calculating the electronic thermal conductivity, the correction due to the thermoelectric power was not made at this time, because there is an anomalous curve of thermopower vs composition at 260 C reported by Wang, et al. [103] which requires further study. Since the corrections are small, no more than 0.2% for all compositions except the 30% Ni alloy, for which it comes to nearly 1% at 260 C, the total thermal conductivity should not be in too large an error without this correction.

For Ni + Fe alloys, the conductivity-composition curve for k_g at 300 K was extrapolated from the Fe + Ni part to the Ni + Fe portion using the k value of Ingersoll [98] (Ni + Fe curve 1) for an alloy with 75.06% Ni as a reference point. That is, the sum of the extrapolated k_g value at 75% Ni and the k_e value calculated from the selected electrical resistivity for

this composition was required to approximate the Ingersoll value. The k_e values for all compositions from 1 to 1100 K were calculated from the selected electrical resistivities, and the k_g values at 300 K were extrapolated to higher temperatures according to the temperature dependence of eq. (35). At low temperatures, all data [81, 100, 105, 106] indicate that k_g is proportional to T, and the k_g values were extrapolated to higher temperature to join the k_g values extrapolated from 300 K to lower temperatures. The total thermal conductivity for each composition was then obtained by adding k_g to k_e, except below 60 K for alloys containing 5% iron or less. The respective ρ_0 values were obtained based solely on the experimental data of ref. [81]. The resulting k values agree with the data of Farrell and Greig [81] (Ni + Fe curves 12–14) and de Nobel [100] (Ni + Fe curve 35) at low temperatures to within 5% and with the data of Ingersoll [98] (Ni + Fe curve 1), Silverman [132] (Ni + Fe curve 2), and Shelton and Swanger [108] (Ni + Fe curves 3–5) at higher temperatures to within 10%. The correction due to the thermoelectric power, which is no more than 2% of the total thermal conductivity for any composition at any temperature, was not made at this time for the same reason as for the Fe + Ni alloys. The recommended values are for totally disordered alloys only; there may be an order-disorder transformation in Ni + Fe alloys over a wide range of compositions.

The recommended values for k, k_e, and k_g are tabulated in Table 25 for 25 alloy compositions, for most of which the temperature range covered is from 4 to 1100 K. These values are for well-annealed disordered alloys. The values for k are also shown in Figures 35 and 36. No values are given for temperatures above 1100 K at this time because there is a phase transformation in iron at 1183 K and it is as yet unknown what effect such a transition has on the lattice thermal conductivity of these alloys. It is noted that at high temperatures the differences between the k values of 5% and 10% nickel alloys are rather large. This is caused by the discontinuity of the Curie temperature at 5.5% nickel, where it drops from 1038 K to 677 K as nickel content increases [104]. The values of residual electrical resistivity for the alloys are also given in Table 25. The uncertainties of the k values are stated in a *footnote* to Table 25, while the uncertainties of the k_e and k_g values are indicated by their being designated as recommended, provisional, or typical values. The ranges of uncertainties of recommended, provisional, and typical values are less than ±15%, between ±15 and ±30%, and greater than ±30%, respectively.

TABLE 25. RECOMMENDED THERMAL CONDUCTIVITY OF IRON-NICKEL ALLOY SYSTEM†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Fe: 99.50% (99.52 At.%) Ni: 0.50% (0.48 At.%)				Fe: 99.00% (99.05 At.%) Ni: 1.00% (0.95 At.%)				Fe: 97.00% (97.14 At.%) Ni: 3.00% (2.96 At.%)				Fe: 95.00% (95.23 At.%) Ni: 5.00% (4.77 At.%)			
ρ_o = 2.06 $\mu\Omega$cm				ρ_o = 3.45 $\mu\Omega$cm				ρ_o = 7.37 $\mu\Omega$cm				ρ_o = 10.37 $\mu\Omega$cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0528*‡			4	0.0322*‡			4	0.0146*	0.0133	0.00125‡	4	0.0102	0.00944	0.000732‡
6	0.0818*‡			6	0.0502*‡			6	0.0224*	0.0199	0.00250‡	6	0.0156	0.0141	0.00147‡
8	0.112*‡			8	0.0690*‡			8	0.0307*	0.0266	0.00408‡	8	0.0213	0.0189	0.00239‡
10	0.144*‡			10	0.0888*‡			10	0.0391*	0.0332	0.00592‡	10	0.0271	0.0236	0.00347‡
15	0.225*‡			15	0.140*‡			15	0.0610*	0.0495	0.0115‡	15	0.0420	0.0352	0.00678‡
20	0.300*‡			20	0.195*‡			20	0.0839	0.0659	0.0180‡	20	0.0573	0.0466	0.0107‡
25	0.396*‡			25	0.251*‡			25	0.107	0.0821	0.0250‡	25	0.0726	0.0576	0.0150‡
30	0.483*‡			30	0.306*‡			30	0.130	0.0979	0.0325‡	30	0.0878	0.0682	0.0196‡
40	0.641*‡			40	0.411*‡			40	0.176	0.128	0.0481‡	40	0.118	0.0886	0.0294‡
50	0.764*‡			50	0.503*‡			50	0.222	0.159	0.0632‡	50	0.146	0.107	0.0391‡
60	0.842*‡	0.577	0.265‡	60	0.573*‡	0.371	0.202‡	60	0.257	0.180	0.0770‡	60	0.173	0.124	0.0485‡
70	0.878*‡	0.590	0.288‡	70	0.618*‡	0.395	0.223‡	70	0.289	0.200	0.0889‡	70	0.195	0.138	0.0568‡
80	0.883*‡	0.583	0.300‡	80	0.643*‡	0.408	0.235‡	80	0.314	0.216	0.0979‡	80	0.214	0.150	0.0638‡
90	0.872*‡	0.569	0.303‡	90	0.654*‡	0.414	0.240‡	90	0.333	0.229	0.104‡	90	0.230	0.161	0.0688‡
100	0.855‡	0.555	0.300‡	100	0.659‡	0.419	0.240‡	100	0.347	0.239	0.108‡	100	0.243	0.171	0.0724‡
150	0.810	0.549	0.261‡	150	0.663	0.450	0.213‡	150	0.393	0.288	0.105‡	150	0.288	0.214	0.0742‡
200	0.785	0.568	0.217§	200	0.666	0.487	0.179§	200	0.421	0.329	0.0923§	200	0.321	0.255	0.0671§
250	0.744	0.562	0.182§	250	0.647	0.496	0.151§	250	0.440	0.360	0.0800§	250	0.344	0.285	0.0589§
273	0.725	0.556	0.169§	273	0.636	0.495	0.141§	273	0.445	0.370	0.0750§	273	0.351	0.296	0.0553§
300	0.701	0.545	0.156§	300	0.623	0.493	0.130§	300	0.450	0.380	0.0695§	300	0.360	0.308	0.0519§
350	0.665	0.529	0.136§	350	0.598	0.485	0.113§	350	0.456	0.395	0.0612§	350	0.372	0.326	0.0458§
400	0.626	0.506	0.120§	400	0.571	0.471	0.100§	400	0.456	0.401	0.0545§	400	0.382	0.341	0.0408§
500	0.564*	0.467	0.0972§	500	0.521	0.440	0.0814§	500	0.448	0.403	0.0446§	500	0.393	0.360	0.0335§
600	0.508*	0.426	0.0817§	600	0.475	0.406	0.0685§	600	0.428	0.390	0.0376§	600	0.385	0.357	0.0284§
700	0.458*	0.388	0.0702§	700	0.436	0.377	0.0591§	700	0.399	0.366	0.0325§	700	0.371	0.346	0.0245§
800	0.412*	0.350	0.0616§	800	0.396	0.344	0.0518§	800	0.366	0.337	0.0286§	800	0.350	0.328	0.0216§
900	0.365*	0.310	0.0548§	900	0.353*	0.307	0.0462§	900	0.330	0.304	0.0255§	900	0.317	0.298	0.0192§
1000	0.318*	0.269	0.0494§	1000	0.309*	0.267	0.0416§	1000	0.293	0.270	0.0230§	1000	0.280	0.263	0.0174§
1100	0.289*	0.244	0.0451§	1100	0.285*	0.247	0.0379§	1100	0.274	0.244	0.0210§	1100	0.268	0.252	0.0158§

† Uncertainties of the total thermal conductivity, k, are as follows:
99.50 Fe – 0.50 Ni: ±15% below 150 K and ±10% above 150 K.
99.00 Fe – 1.00 Ni: ±15% below 150 K and ±10% above 150 K.
97.00 Fe – 3.00 Ni: ±10% below 100 K, ±5% between 100 and 500 K, and ±8% above 500 K.
95.00 Fe – 5.00 Ni: ±10% below 100 K, ±5% between 100 and 500 K, and ±8% above 500 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 25. RECOMMENDED THERMAL CONDUCTIVITY OF IRON-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Fe: 90.00% (90.24 At.%) Ni: 10.00% (9.76 At.%)				Fe: 85.00% (85.63 At.%) Ni: 15.00% (14.37 At.%)				Fe: 80.00% (80.79 At.%) Ni: 20.00% (19.21 At.%)				Fe: 75.00% (75.93 At.%) Ni: 25.00% (24.07 At.%)			
ρ_o = 16.50 μΩcm				ρ_o = 19.22 μΩcm				ρ_o = 22.11 μΩcm				ρ_o = 27.69 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.00628	0.00592	0.000364‡	4	0.00535	0.00508	0.000267‡	4	0.00461	0.00440	0.000214‡	4	0.00371	0.00353	0.000177‡
6	0.00960	0.00886	0.000732‡	6	0.00815	0.00761	0.000538‡	6	0.00703	0.00660	0.000431‡	6	0.00564	0.00528	0.000358‡
8	0.0130	0.0118	0.00120‡	8	0.0110	0.0102	0.000881‡	8	0.00951	0.00880	0.000710‡	8	0.00763	0.00704	0.000586‡
10	0.0166	0.0148	0.00176‡	10	0.0140	0.0127	0.00129‡	10	0.0120	0.0110	0.00104‡	10	0.00968	0.00882	0.000860‡
15	0.0256	0.0221	0.00345‡	15	0.0214	0.0189	0.00253‡	15	0.0184	0.0163	0.00205‡	15	0.0149	0.0132	0.00170‡
20	0.0350	0.0296	0.00548‡	20	0.0291	0.0251	0.00405‡	20	0.0249	0.0216	0.00328‡	20	0.0201	0.0174	0.00273‡
25	0.0442	0.0365	0.00775‡	25	0.0370	0.0312	0.00575‡	25	0.0315	0.0269	0.00464‡	25	0.0252	0.0213	0.00389‡
30	0.0538	0.0436	0.0102‡	30	0.0449	0.0373	0.00760‡	30	0.0381	0.0320	0.00614‡	30	0.0305	0.0253	0.00515‡
40	0.0727	0.0573	0.0154‡	40	0.0606	0.0490	0.0116‡	40	0.0513	0.0420	0.00934‡	40	0.0412	0.0333	0.00785‡
50	0.0912	0.0705	0.0207‡	50	0.0759	0.0602	0.0157‡	50	0.0644	0.0517	0.0127‡	50	0.0516	0.0409	0.0107‡
60	0.109	0.0827	0.0260‡	60	0.0906	0.0709	0.0196‡	60	0.0767	0.0607	0.0160‡	60	0.0616	0.0481	0.0135‡
70	0.125	0.0939	0.0309‡	70	0.104	0.0806	0.0236‡	70	0.0885	0.0692	0.0193‡	70	0.0711	0.0548	0.0163‡
80	0.139	0.104	0.0354‡	80	0.117*	0.0896	0.0271‡	80	0.0992*	0.0769	0.0223‡	80	0.0801	0.0612	0.0189‡
90	0.152	0.113	0.0391‡	90	0.128*	0.0978	0.0304‡	90	0.109*	0.0841	0.0250‡	90	0.0884	0.0671	0.0213‡
100	0.164	0.122	0.0421‡	100	0.138*	0.105	0.0329‡	100	0.118*	0.0909	0.0174‡	100	0.0959	0.0726	0.0233‡
150	0.206	0.159	0.0468‡	150	0.177*	0.139	0.0377‡	150	0.154*	0.122	0.0321‡	150	0.126	0.0980	0.0260‡
200	0.234	0.190	0.0437§	200	0.204*	0.168	0.0360§	200	0.178*	0.147	0.0310§	200	0.147	0.119	0.0276§
250	0.255	0.216	0.0390§	250	0.223*	0.190	0.0326§	250	0.197*	0.169	0.0285§	250	0.162	0.137	0.0253§
273	0.262	0.225	0.0370§	273	0.231	0.200	0.0310§	273	0.205	0.178	0.0271§	273	0.168	0.144	0.0242§
300	0.270	0.236	0.0349§	300	0.238	0.209	0.0294§	300	0.212	0.186	0.0256§	300	0.174	0.151	0.0229§
350	0.282*	0.251	0.0311§	350	0.250*	0.224	0.0263§	350	0.225	0.202	0.0231§	350	0.184	0.163	0.0207§
400	0.292*	0.264	0.0279§	400	0.260*	0.236	0.0236§	400	0.235	0.214	0.0208§	400	0.191	0.172	0.0167§
500	0.305*	0.282	0.0231§	500	0.274*	0.254	0.0296§	500	0.249	0.232	0.0173§	500	0.203	0.187	0.0157§
600	0.306*	0.286	0.0196§	600	0.280*	0.263	0.0166§	600	0.255	0.240	0.0147§	600	0.210	0.197	0.0133§
700	0.302*	0.285	0.0169§	700	0.278*	0.264	0.0144§	700	0.253	0.240	0.0128§	700	0.212	0.200	0.0116§
800	0.290*	0.275	0.0149§	800	0.264*	0.251	0.0128§	800	0.244	0.233	0.0113§	800	0.208	0.198	0.0102§
900	0.267*	0.254	0.0133§	900	0.245*	0.234	0.0114§	900	0.230*	0.220	0.0101§	900	0.208*	0.199	0.00914§
1000	0.240*	0.228	0.0121§	1000	0.231*	0.221	0.0103§	1000	0.224*	0.215	0.00911§	1000	0.213*	0.205	0.00828§
1100	0.234*	0.223	0.0110§	1100	0.230*	0.221	0.00939§	1100	0.228*	0.220	0.00837§	1100	0.221*	0.213	0.0077[illegible]§

† Uncertainties of the total thermal conductivity, k, are as follows:

90.00 Fe - 10.00 Ni: ± 10% below 100 K, ± 5% between 100 and 500 K, and ± 10% above 500 K.
85.00 Fe - 15.00 Ni: ± 10% below 100 K, ± 5% between 100 and 500 K, and ± 10% above 500 K.
80.00 Fe - 20.00 Ni: ± 10% below 100 K, ± 5% between 100 and 500 K, and ± 10% above 500 K.
75.00 Fe - 25.00 Ni: ± 10% below 100 K, ± 5% between 100 and 500 K, and ± 10% above 500 K.

* Provisional value.

‡ Typical value.

§ In temperature range where no experimental thermal conductivity data are available.

TABLE 35. RECOMMENDED THERMAL CONDUCTIVITY OF IRON-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm⁻¹ K⁻¹; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Fe: 70.00% (71.04 At.%) Ni: 30.00% (28.96 At.%)				Fe: 65.00% (66.13 At.%) Ni: 35.00% (33.87 At.%)				Fe: 60.00% (61.19 At.%) Ni: 40.00% (38.81 At.%)				Fe: 55.00% (56.23 At.%) Ni: 45.00% (43.77 At.%)			
ρ_0 = 61.78 μΩcm				ρ_0 = 67.04 μΩcm				ρ_0 = 25.86 μΩcm				ρ_0 = 18.64 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.00174‡	0.00158	0.000156§	4	0.00160‡	0.00146	0.000145§	4	0.00549‡	0.00378	0.00171‡	4	0.00690*‡	0.00524	0.00166‡
6	0.00270‡	0.00238	0.000315§	6	0.00248‡	0.00219	0.000291‡	6	0.00826‡	0.00567	0.00259‡	6	0.0104*‡	0.00784	0.00251‡
8	0.00368‡	0.00317	0.000515‡	8	0.00338‡	0.00290	0.000480‡	8	0.0110‡	0.00758	0.00345‡	8	0.0138*‡	0.0104	0.00335‡
10	0.00470‡	0.00395	0.000755‡	10	0.00434‡	0.00364	0.000700‡	10	0.0137‡	0.00936	0.00431‡	10	0.0171*‡	0.0129	0.00418‡
15	0.00734‡	0.00584	0.00150‡	15	0.00681‡	0.00542	0.00139‡	15	0.0202‡	0.0138	0.00645‡	15	0.0252*‡	0.0189	0.00625‡
20	0.0101‡	0.00770	0.00240§	20	0.00939‡	0.00715	0.00224‡	20	0.0268‡	0.0182	0.00857‡	20	0.0330*‡	0.0247	0.00830‡
25	0.0130‡	0.00956	0.00342‡	25	0.0120‡	0.00884	0.00317‡	25	0.0330‡	0.0223	0.0107‡	25	0.0405*‡	0.0302	0.0103‡
30	0.0159‡	0.0114	0.00452§	30	0.0147‡	0.0105	0.00422‡	30	0.0391‡	0.0264	0.0127‡	30	0.0479*‡	0.0356	0.0123‡
40	0.0219‡	0.0150	0.00694§	40	0.0203‡	0.0139	0.00644‡	40	0.0509‡	0.0343	0.0166‡	40	0.0620*‡	0.0459	0.0161‡
50	0.0279‡	0.0185	0.00940§	50	0.0258‡	0.0171	0.00871‡	50	0.0618‡	0.0418	0.0200‡	50	0.0748*‡	0.0554	0.0194‡
60	0.0339‡	0.0219	0.0120§	60	0.0315‡	0.0203	0.0112‡	60	0.0716‡	0.0487	0.0229‡	60	0.0858*‡	0.0640	0.0218‡
70	0.0396‡	0.0251	0.0145§	70	0.0368‡	0.0233	0.0135‡	70	0.0802‡	0.0550	0.0252‡	70	0.0963*‡	0.0718	0.0245‡
80	0.0451‡	0.0282	0.0169‡	80	0.0419‡	0.0262	0.0157‡	80	0.0878‡	0.0608	0.0270‡	80	0.105*‡	0.0787	0.0262‡
90	0.0502‡	0.0312	0.0190§	90	0.0469‡	0.0291	0.0178‡	90	0.0944‡	0.0661	0.0283‡	90	0.112*‡	0.0848	0.0275‡
100	0.0550‡	0.0341	0.0209‡	100	0.0514‡	0.0318	0.0196‡	100	0.100‡	0.0710	0.0291‡	100	0.119*‡	0.0905	0.0283‡
150	0.0731‡	0.0476	0.0255§	150	0.0687‡	0.0446	0.0241‡	150	0.119‡	0.0910	0.0282‡	150	0.141‡	0.113	0.0275‡
200	0.0850‡	0.0597	0.0253‡	200	0.0802‡	0.0562	0.0240‡	200	0.130	0.105	0.0250‡	200	0.154	0.129	0.0244‡
250	0.0940‡	0.0705	0.0235§	250	0.0890	0.0666	0.0224‡	250	0.137	0.115	0.0220‡	250	0.162	0.140	0.0215‡
273	0.0976‡	0.0752	0.0224§	273	0.0924	0.0710	0.0214‡	273	0.139	0.118	0.0208‡	273	0.164	0.144	0.0203‡
300	0.101‡	0.0803	0.0212‡	300	0.0961	0.0759	0.0202‡	300	0.140	0.121	0.0196‡	300	0.167	0.148	0.0191‡
350	0.109	0.0901	0.0192§	350	0.103	0.0846	0.0184‡	350	0.143	0.125	0.0175‡	350	0.171	0.154	0.0168‡
400	0.115	0.0975	0.0174‡	400	0.109	0.0928	0.0166‡	400	0.144	0.128	0.2158‡	400	0.173	0.157	0.0156‡
500	0.129	0.114	0.0148§	500	0.122	0.108	0.0139‡	500	0.147	0.133	0.0133‡	500	0.176	0.163	0.0131‡
600	0.142	0.130	0.0124§	600	0.137	0.125	0.0119‡	600	0.152	0.140	0.0115‡	600	0.178	0.167	0.0113‡
700	0.158	0.147	0.0108‡	700	0.153	0.143	0.0103‡	700	0.165	0.155	0.0100‡	700	0.184	0.174	0.00988‡
800	0.175	0.165	0.00950§	800	0.169	0.160	0.00913‡	800	0.182	0.173	0.00893‡	800	0.198	0.189	0.00882‡
900	0.189*	0.180	0.00849‡	900	0.183*	0.175	0.00818‡	900	0.197*	0.189	0.00807‡	900	0.213	0.205	0.00795‡
1000	0.200*	0.192	0.00771‡	1000	0.195*	0.188	0.00740‡	1000	0.209*	0.202	0.00736‡	1000	0.225	0.218	0.00725‡
1100	0.210*	0.203	0.00704‡	1100	0.204*	0.197	0.00676‡	1100	0.219*	0.213	0.00679‡	1100	0.236	0.230	0.00668‡

† Uncertainties of the total thermal conductivity, k, are as follows:
70.00 Fe - 30.00 Ni: ±15% below 200 K, and ±10% above 200 K.
65.00 Fe - 35.00 Ni: ±15% below 200 K, and ±10% above 200 K.
60.00 Fe - 40.00 Ni: ±20% below 150 K, ±10% between 150 and 500 K, and ±12% above 500 K.
55.00 Fe - 45.00 Ni: ±20% below 150 K, ±8% between 150 and 500 K, and ±10% above 500 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 25. RECOMMENDED THERMAL CONDUCTIVITY OF IRON-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Fe: 50.00% (51.25 At.%) Ni: 50.00% (48.75 At.%)				Fe: 45.00% (46.24 At.%) Ni: 55.00% (53.76 At.%)				Fe: 40.00% (41.21 At.%) Ni: 60.00% (38.79 At.%)				Fe: 35.00% (36.15 At.%) Ni: 65.00% (63.85 At.%)			
ρ_0 = 14.67 μΩcm				ρ_0 = 12.17 μΩcm				ρ_0 = 10.23 μΩcm				ρ_0 = 8.81 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.00820*‡	0.00661	0.00159§	4	0.00950	0.00793	0.00157§	4	0.0111*	0.00949	0.00163§	4	0.0128*	0.0111	0.00171§
6	0.0122*‡	0.00979	0.00239§	6	0.0142	0.0119	0.00238§	6	0.0168*	0.0143	0.00247§	6	0.0191*	0.0165	0.00259§
8	0.0163*‡	0.0131	0.00319§	8	0.0187	0.0157	0.00318§	8	0.0223*	0.0190	0.00330§	8	0.0254*	0.0220	0.00345§
10	0.0202*‡	0.0162	0.00399§	10	0.0234	0.0194	0.00397§	10	0.0276*	0.0235	0.00412§	10	0.0316*	0.0273	0.00431§
15	0.0297‡	0.0237	0.00598§	15	0.0344	0.0285	0.00594§	15	0.0404*	0.0343	0.00615§	15	0.0468*	0.0403	0.00645§
20	0.0389‡	0.0309	0.00796§	20	0.0451	0.0372	0.00791§	20	0.0530*	0.0448	0.00816§	20	0.0614*	0.0528	0.00857§
25	0.0477‡	0.0378	0.00988§	25	0.0556	0.0458	0.00980§	25	0.0649*	0.0548	0.0101§	25	0.0753*	0.0646	0.0107§
30	0.0563‡	0.0445	0.0118§	30	0.0656	0.0539	0.0117§	30	0.0766*	0.0644	0.0122§	30	0.0886*	0.0759	0.0127§
40	0.0722‡	0.0568	0.0154§	40	0.0840	0.0688	0.0152§	40	0.0981*	0.0823	0.0158§	40	0.113*	0.0964	0.0166§
50	0.0867‡	0.0681	0.0186§	50	0.100	0.0821	0.0184§	50	0.117*	0.0980	0.0191§	50	0.134*	0.114	0.0200§
60	0.0991‡	0.0779	0.0212§	60	0.114	0.0930	0.0210§	60	0.134*	0.112	0.0218§	60	0.152*	0.129	0.0229§
70	0.110‡	0.0861	0.0235§	70	0.128	0.104	0.0233§	70	0.147*	0.123	0.0240§	70	0.167*	0.142	0.0252§
80	0.119‡	0.0943	0.0251§	80	0.138	0.113	0.0250§	80	0.159*	0.133	0.0258§	80	0.179*	0.152	0.0270§
90	0.127‡	0.101	0.0264§	90	0.146	0.120	0.0262§	90	0.168*	0.141	0.0270§	90	0.188*	0.159	0.0283§
100	0.135‡	0.108	0.0271§	100	0.154	0.127	0.0270§	100	0.176*	0.148	0.0278§	100	0.195*	0.166	0.0291§
150	0.158‡	0.131	0.0265§	150	0.178	0.151	0.0263§	150	0.200*	0.173	0.0270§	150	0.219*	0.190	0.0282§
200	0.172	0.149	0.0236§	200	0.193	0.169	0.0235§	200	0.213*	0.189	0.0240§	200	0.232*	0.207	0.0250§
250	0.182	0.162	0.0206§	250	0.202	0.182	0.0207§	250	0.221*	0.200	0.0211§	250	0.238*	0.216	0.0220§
273	0.186	0.167	0.0197§	273	0.205	0.185	0.0197§	273	0.223*	0.203	0.0200§	273	0.240*	0.219	0.0208§
300	0.190	0.171	0.0186§	300	0.209	0.190	0.0185§	300	0.226*	0.207	0.0188§	300	0.242*	0.222	0.0196§
350	0.195	0.178	0.0167§	350	0.213	0.196	0.0167§	350	0.228*	0.211	0.0169§	350	0.244*	0.226	0.0175§
400	0.199	0.184	0.0152§	400	0.216	0.201	0.0151§	400	0.230*	0.215	0.0153§	400	0.245*	0.229	0.0158§
500	0.203	0.190	0.0128§	500	0.220	0.207	0.0127§	500	0.233*	0.220	0.0129§	500	0.247*	0.234	0.0133§
600	0.204	0.193	0.0110§	600	0.221	0.210	0.0109§	600	0.235*	0.224	0.0111§	600	0.249*	0.237	0.0115§
700	0.207	0.197	0.00962§	700	0.224	0.215	0.00958§	700	0.238*	0.228	0.00974§	700	0.253*	0.243	0.0100§
800	0.210	0.202	0.00858§	800	0.229	0.221	0.00854§	800	0.246*	0.237	0.00868§	800	0.262*	0.253	0.00893§
900	0.223	0.215	0.00774§	900	0.241	0.233	0.00771§	900	0.259*	0.251	0.00783§	900	0.276*	0.268	0.00807§
1000	0.235	0.228	0.00709§	1000	0.255	0.248	0.00701§	1000	0.273*	0.266	0.00714§	1000	0.291*	0.284	0.00730§
1100	0.245	0.239	0.00651§	1100	0.266	0.260	0.00648§	1100	0.286*	0.280	0.00659§	1100	0.304*	0.297	0.00679§

† Uncertainties of the total thermal conductivity, k, are as follows:
50.00 Fe - 50.00 Ni: ±15% below 150 K, ±6% between 150 and 500 K, and ±8% above 150 K.
45.00 Fe - 55.00 Ni: ±12% below 100 K, ±8% between 100 and 500 K, and ±10% above 500 K.
40.00 Fe - 60.00 Ni: ±12% below 200 K and ±8% above 200 K.
35.00 Fe - 65.00 Ni: ±12% below 200 K and ±8% above 200 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 25. RECOMMENDED THERMAL CONDUCTIVITY OF IRON-NICKEL ALLOY SYSTEM (*continued*) †

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Fe: 30.00% (31.06 At.%) Ni: 70.00% (68.94 At.%)				Fe: 25.00% (25.95 At.%) Ni: 75.00% (74.05 At.%)				Fe: 20.00% (20.81 At.%) Ni: 80.00% (79.19 At.%)				Fe: 15.00% (15.65 At.%) Ni: 85.00% (84.35 At.%)			
ρ_0 = 7.53 μΩcm				ρ_0 = 6.25 μΩcm				ρ_0 = 5.04 μΩcm				ρ_0 = 3.935 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0146	0.0128	0.00183‡	4	0.0176	0.0156	0.00198‡	4	0.0217	0.0194	0.00230‡	4	0.0275‡	0.0248	0.00266‡
6	0.0218*	0.0190	0.00276‡	6	0.0262*	0.0232	0.00300‡	6	0.0324*	0.0289	0.00346‡	6	0.0410‡	0.0370	0.00401‡
8	0.0290*	0.0253	0.00370‡	8	0.0345*	0.0305	0.00401‡	8	0.0429*	0.0383	0.00462‡	8	0.0543‡	0.0489	0.00538‡
10	0.0360*	0.0314	0.00462‡	10	0.0429*	0.0379	0.00503‡	10	0.0533*	0.0475	0.00578‡	10	0.0674‡	0.0607	0.00675‡
15	0.0527*	0.0458	0.00687‡	15	0.0628*	0.0552	0.00759‡	15	0.0778*	0.0692	0.00864‡	15	0.0985‡	0.0884	0.0101‡
20	0.0687*	0.0596	0.00912‡	20	0.0815*	0.0714	0.0101‡	20	0.101*	0.0896	0.0116‡	20	0.128‡	0.114	0.0135‡
25	0.0843*	0.0730	0.0113‡	25	0.0990*	0.0863	0.0127‡	25	0.122*	0.108	0.0144‡	25	0.155‡	0.138	0.0168‡
30	0.0988*	0.0850	0.0138‡	30	0.116*	0.100	0.0151‡	30	0.142*	0.125	0.0172‡	30	0.181‡	0.161	0.0200‡
40	0.124*	0.106	0.0176‡	40	0.145*	0.125	0.0197‡	40	0.177*	0.155	0.0224‡	40	0.224‡	0.198	0.0261‡
50	0.148*	0.127	0.0213‡	50	0.170*	0.146	0.0237‡	50	0.206*	0.179	0.0269‡	50	0.258‡	0.227	0.0312‡
60	0.167*	0.143	0.0243‡	60	0.190*	0.163	0.0270‡	60	0.228*	0.197	0.0306‡	60	0.284‡	0.249	0.0354‡
70	0.184*	0.157	0.0268‡	70	0.206*	0.176	0.0295‡	70	0.245*	0.212	0.0334‡	70	0.303‡	0.264	0.0394‡
80	0.196*	0.168	0.0286‡	80	0.219*	0.187	0.0315‡	80	0.259*	0.223	0.0355‡	80	0.316‡	0.276	0.0406‡
90	0.206*	0.176	0.0300‡	90	0.228*	0.196	0.0327‡	90	0.268*	0.231	0.0367‡	90	0.324*‡	0.282	0.0420‡
100	0.213*	0.183	0.0306‡	100	0.236*	0.203	0.0336‡	100	0.275*	0.238	0.0375‡	100	0.329*‡	0.286	0.0426‡
150	0.236*	0.206	0.0295‡	150	0.257*	0.225	0.0320‡	150	0.295*	0.260	0.0351‡	150	0.342*	0.303	0.0395‡
200	0.248*	0.222	0.0260‡	200	0.268*	0.240	0.0282‡	200	0.305*	0.274	0.0308‡	200	0.348*	0.313	0.0344‡
250	0.255*	0.232	0.0229‡	250	0.274*	0.249	0.0248‡	250	0.309*	0.282	0.0270‡	250	0.350*	0.320	0.0300‡
273	0.257*	0.235	0.0216‡	273	0.276*	0.252	0.0233‡	273	0.309*	0.284	0.0254‡	273	0.350*	0.322	0.0281‡
300	0.256*	0.236	0.0203‡	300	0.277	0.256	0.0218‡	300	0.310	0.286	0.0237‡	300	0.351*	0.324	0.0264‡
350	0.260*	0.242	0.0181‡	350	0.279	0.259	0.0195‡	350	0.311	0.290	0.0211‡	350	0.350*	0.327	0.0234‡
400	0.261*	0.245	0.0163‡	400	0.280*	0.262	0.0175‡	400	0.311*	0.292	0.0190‡	400	0.352*	0.331	0.0210‡
500	0.263*	0.249	0.0137‡	500	0.280*	0.265	0.0146‡	500	0.310*	0.294	0.0158‡	500	0.348*	0.330	0.0175‡
600	0.264*	0.252	0.0118‡	600	0.279*	0.267	0.0125‡	600	0.308*	0.294	0.0136‡	600	0.342*	0.327	0.0150‡
700	0.267*	0.257	0.0103‡	700	0.281*	0.270	0.0109‡	700	0.309*	0.297	0.0119‡	700	0.338*	0.325	0.0131‡
800	0.275*	0.266	0.00918‡	800	0.290*	0.280	0.00971‡	800	0.311*	0.300	0.0106‡	800	0.333*	0.322	0.0117‡
900	0.292*	0.284	0.00836‡	900	0.305*	0.296	0.00876‡	900	0.324*	0.315	0.00949‡	900	0.346*	0.336	0.0105‡
1000	0.308*	0.300	0.00754‡	1000	0.321*	0.313	0.00798‡	1000	0.340*	0.331	0.00863‡	1000	0.362*	0.353	0.00950‡
1100	0.320*	0.313	0.00696‡	1100	0.338*	0.330	0.00734‡	1100	0.356*	0.348	0.00796‡	1100	0.378*	0.369	0.00876‡

† Uncertainties of the total thermal conductivity, k, are as follows:
30.00 Fe - 70.00 Ni: ±12% below 200 K and ±8% above 200 K.
25.00 Fe - 75.00 Ni: ±10% below 100 K, ±6% between 100 and 500 K, and ±8% above 500 K.
20.00 Fe - 80.00 Ni: ±12% below 100 K, ±6% between 100 and 500 K, and ±8% above 500 K.
15.00 Fe - 85.00 Ni: ±15% below 100 K, ±8% between 100 and 500 K, and ±10% above 100 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 25. RECOMMENDED THERMAL CONDUCTIVITY OF IRON-NICKEL ALLOY SYSTEM (continued) †

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Fe: 10.00% (10.46 At.%) Ni: 90.00% (89.54 At.%)				Fe: 5.00% (5.24 At.%) Ni: 95.00% (94.76 At.%)				Fe: 3.00% (3.15 At.%) Ni: 97.00% (96.85 At.%)				Fe: 1.00% (1.05 At.%) Ni: 99.00% (98.95 At.%)			
ρ_0 = 2.962 μΩcm				ρ_0 = 2.045 μΩcm				ρ_0 = 1.227 μΩcm				ρ_0 = 0.409 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	[illegible]	[illegible]	[illegible]	4	0.0741‡			4	0.115‡			4	0.[illegible]‡		
6	[illegible]	0.0614	[illegible]	6	0.109‡			6	0.168‡			6	0.479‡		
8	0.07[illegible]‡	0.0[illegible]1	0.00720§	8	0.143‡			8	0.221‡			8	0.6[illegible]‡		
10	[illegible]	[illegible]	0.00901§	10	0.177‡			10	0.273‡			10	0.777‡		
15	0.13[illegible]‡	0.123	0.01[illegible]§	15	0.256‡			15	0.396‡			15	1.00‡		
20	0.170‡	0.156	0.0150§	20	0.326‡			20	0.503‡			20	1.37‡		
25	0.213‡	0.191	0.022[illegible]§	25	0.388‡			25	0.590‡			25	1.53‡		
30	0.247‡	0.221	0.02[illegible]§	30	0.440‡			30	0.659‡			30	1.60‡		
40	0.304‡	0.270	0.0345§	40	0.520‡			40	0.751‡			40	1.56‡		
50	0.347‡	0.306	0.0410§	50	0.565‡			50	0.791‡			50	1.42‡		
60	0.376‡	0.3[illegible]	0.0461§	60	0.583‡			60	0.794‡			60	1.30‡		
70	0.396‡	0.346	0.0496§	70	0.588‡			70	0.782‡			70	1.20‡		
80	0.408‡	0.356	0.0521§	80	0.585‡			80	0.768‡			80	1.13‡		
90	0.414*‡	0.361	0.0553§	90	0.578‡			90	0.745‡			90	1.07‡		
100	0.417*‡	0.364	0.0537§	100	0.570‡	0.471	0.0993§	100	0.726‡	0.580	0.146§	100	1.02‡	0.766	0.255§
150	0.40[illegible]*	0.360	0.0486§	150	0.543*	0.459	0.0838§	150	0.657*	0.540	0.117§	150	0.880*	0.686	0.194§
200	0.40[illegible]*	0.366	0.0419§	200	0.535*	0.466	0.0691§	200	0.626*	0.533	0.0947§	200	0.814*	0.662	0.1[illegible]§
250	0.41[illegible]*	0.373	0.0363§	250	0.529*	0.471	0.0584§	250	0.608*	0.529	0.0794§	250	0.767*	0.643	0.124§
273	0.41[illegible]*	0.376	0.0341§	273	0.525*	0.470	0.0545§	273	0.603*	0.529	0.0739§	273	0.751*	0.636	0.115§
300	0.410*	0.378	0.0318§	300	0.521*	0.470	0.0505§	300	0.596*	0.528	0.0680§	300	0.735*	0.629	0.106§
350	0.40[illegible]*	0.380	0.0282§	350	0.514*	0.469	0.0448§	350	0.585*	0.525	0.0596§	350	0.704	0.612	0.0913§
400	0.40[illegible]*	0.379	0.0253§	400	0.504*	0.464	0.0400§	400	0.570*	0.517	0.0531§	400	0.676	0.596	0.080[illegible]§
500	0.3[illegible]*	0.378	0.0210§	500	0.484*	0.451	0.0328§	500	0.540*	0.496	0.0435§	500	0.623	0.557	0.0656§
600	0.3[illegible]*	0.371	0.0180§	600	0.455*	0.427	0.0278§	600	0.504*	0.467	0.0367§	600	0.575	0.520	0.0543§
700	0.37[illegible]*	0.360	0.0157§	700	0.420*	0.396	0.0240§	700	0.480*	0.448	0.0318§	700	0.563	0.517	0.0468§
800	0.3[illegible]*	0.354	0.0139§	800	0.436*	0.415	0.0211§	800	0.496*	0.468	0.0280§	800	0.582	0.541	0.0410§
900	0.3[illegible]*	0.3[illegible]	0.0126§	900	0.450*	0.431	0.0189§	900	0.513*	0.488	0.0249§	900	0.601*	0.564	0.0364§
1000	0.3[illegible]*	0.3[illegible]	0.0114§	1000	0.465*	0.448	0.0170§	1000	0.529*	0.507	0.0225§	1000	0.620*	0.588	0.03[illegible]§
1100	0.4[illegible]*	0.3[illegible]	0.0105§	1100	0.479*	0.463	0.0155§	1100	0.546*	0.526	0.0205§	1100	0.640*	0.610	0.0299§

† Uncertainties of the total thermal conductivity, k, are as follows:
10.00 Fe - 90.00 Ni: ±15% below 100 K, ±8% between 100 and 500 K, and ±10% above 500 K.
5.00 Fe - 95.00 Ni: ±15% below 150 K, ±6% between 150 and 500 K, and ±8% above 500 K.
3.00 Fe - 97.00 Ni: ±15% below 150 K, ±6% between 150 and 500 K, and ±8% above 500 K.
1.00 Fe - 99.00 Ni: ±15% below 80 K, ±10% between 80 and 200 K, and ±6% above 200 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 25. RECOMMENDED THERMAL CONDUCTIVITY OF IRON-NICKEL ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Fe: 0.50% (0.48 At.%)
Ni: 99.50% (99.52 At.%)

ρ_0 = 0.2045 $\mu\Omega$cm

T	k	k_e	k_g
4	0.829‡		
6	1.22‡		
8	1.59‡		
10	1.95‡		
15	2.76‡		
20	3.26‡		
25	3.44‡		
30	3.35‡		
40	2.94‡		
50	2.40‡		
60	1.96‡		
70	1.69‡		
80	1.49‡		
90	1.35‡		
100	1.24‡	0.938	0.301§
150	0.991*	0.765	0.226§
200	0.892*	0.715	0.177§
250	0.833*	0.688	0.145§
273	0.811*	0.678	0.133§
300	0.789*	0.666	0.123§
350	0.749	0.643	0.106§
400	0.714	0.621	0.0932§
500	0.653	0.578	0.0752§
600	0.600	0.537	0.0630§
700	0.593	0.539	0.0542§
800	0.612	0.565	0.0474§
900	0.632*	0.591	0.0422§
1000	0.653*	0.615	0.0380§
1100	0.676*	0.641	0.0346§

† Uncertainties of the total thermal conductivity, k, are as follows:
0.50 Fe - 99.50 Ni: ±20% below 80 K, ±10% between 80 and 200 K, and ±6% above 200 K.

‡ Provisional value.

§ Typical value.

* In temperature range where no experimental thermal conductivity data are available.

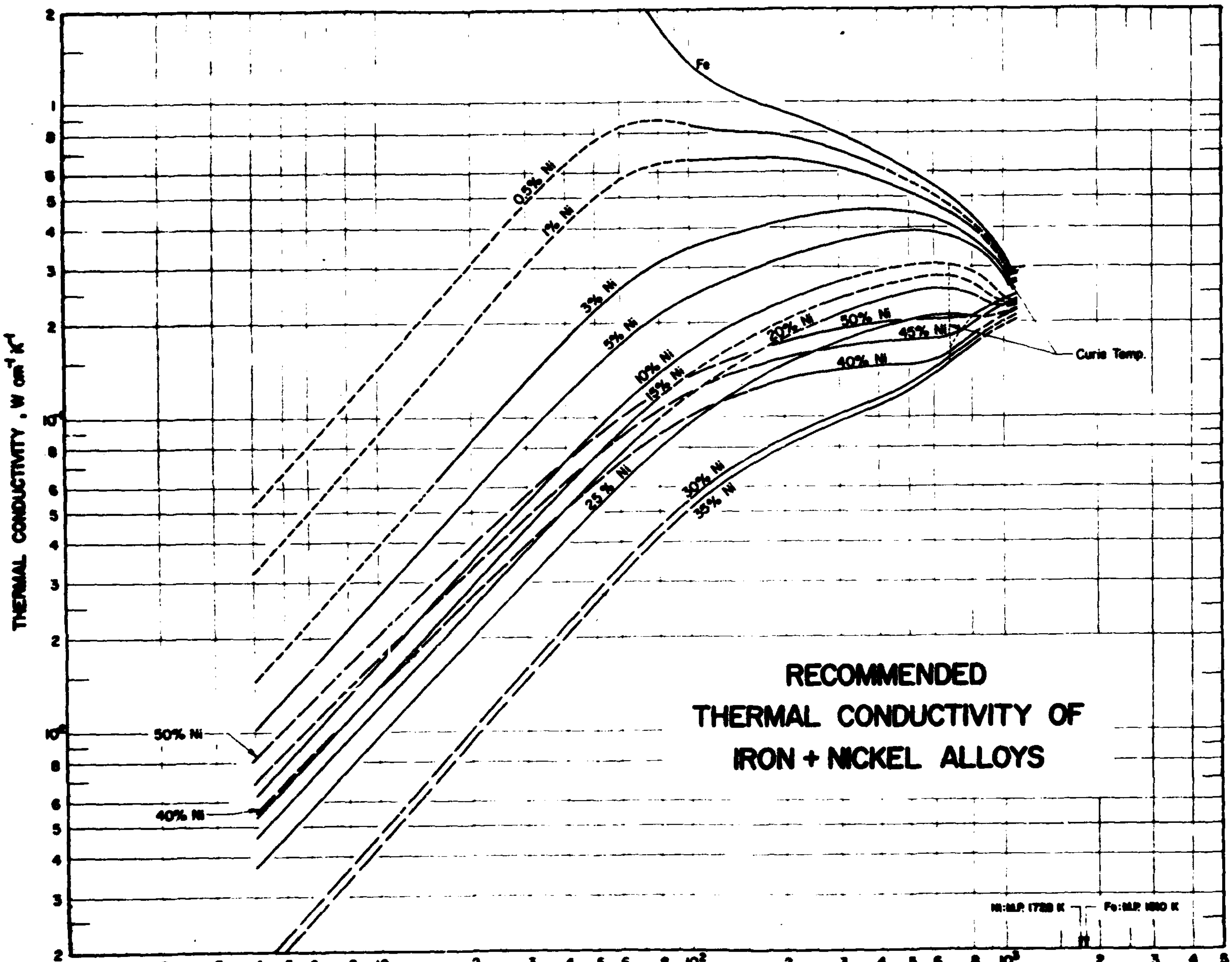


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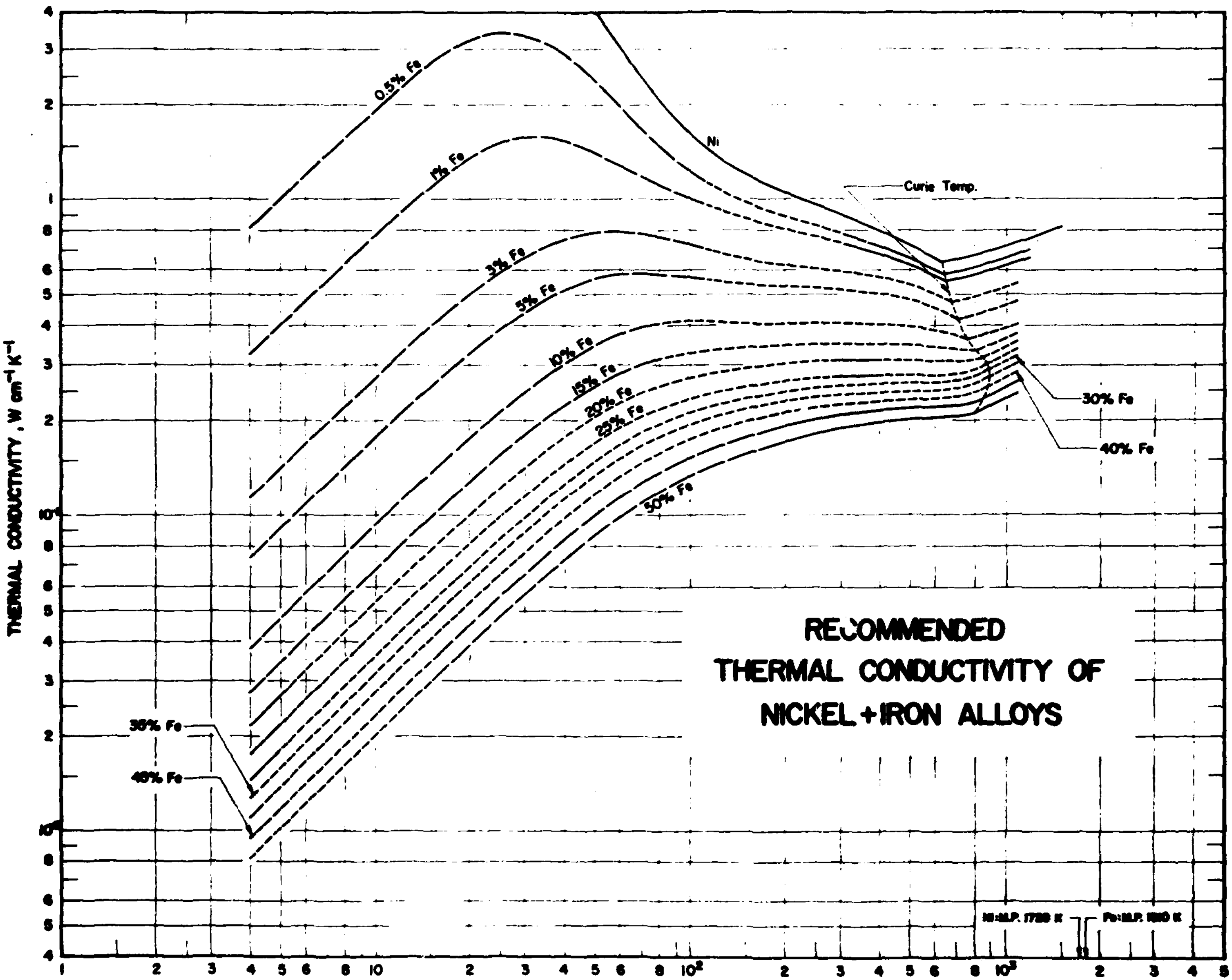
FIGURE 35



TPRC FIGURE 36

AD-A129 405 THERMAL CONDUCTIVITY OF TEN SELECTED BINARY ALLOY SYSTEMS(U) THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER LAFAYETTE IN C Y HO ET AL. 3/3

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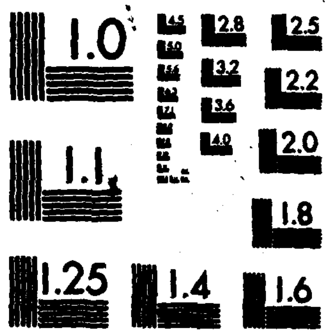

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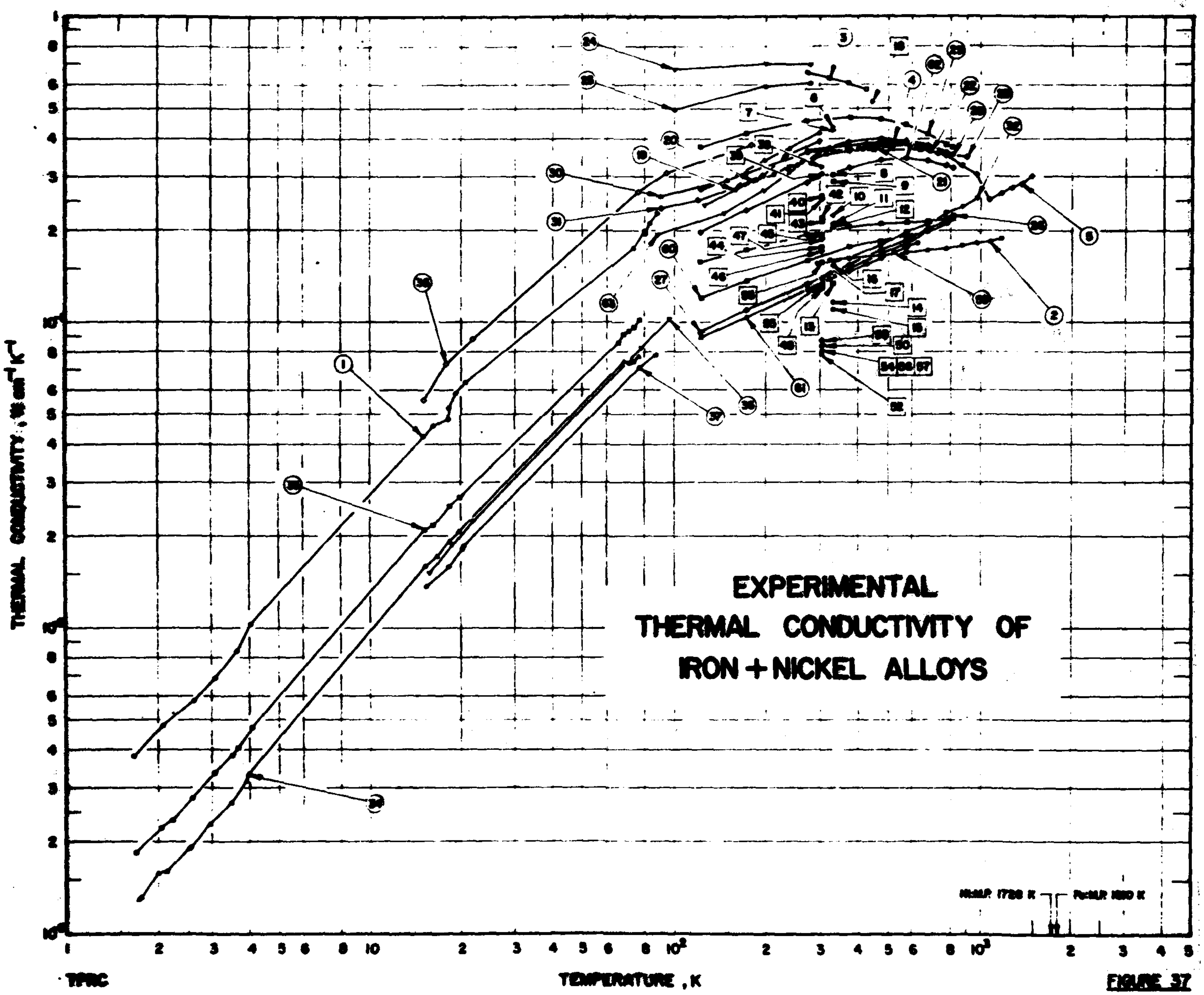

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FIGURE 37

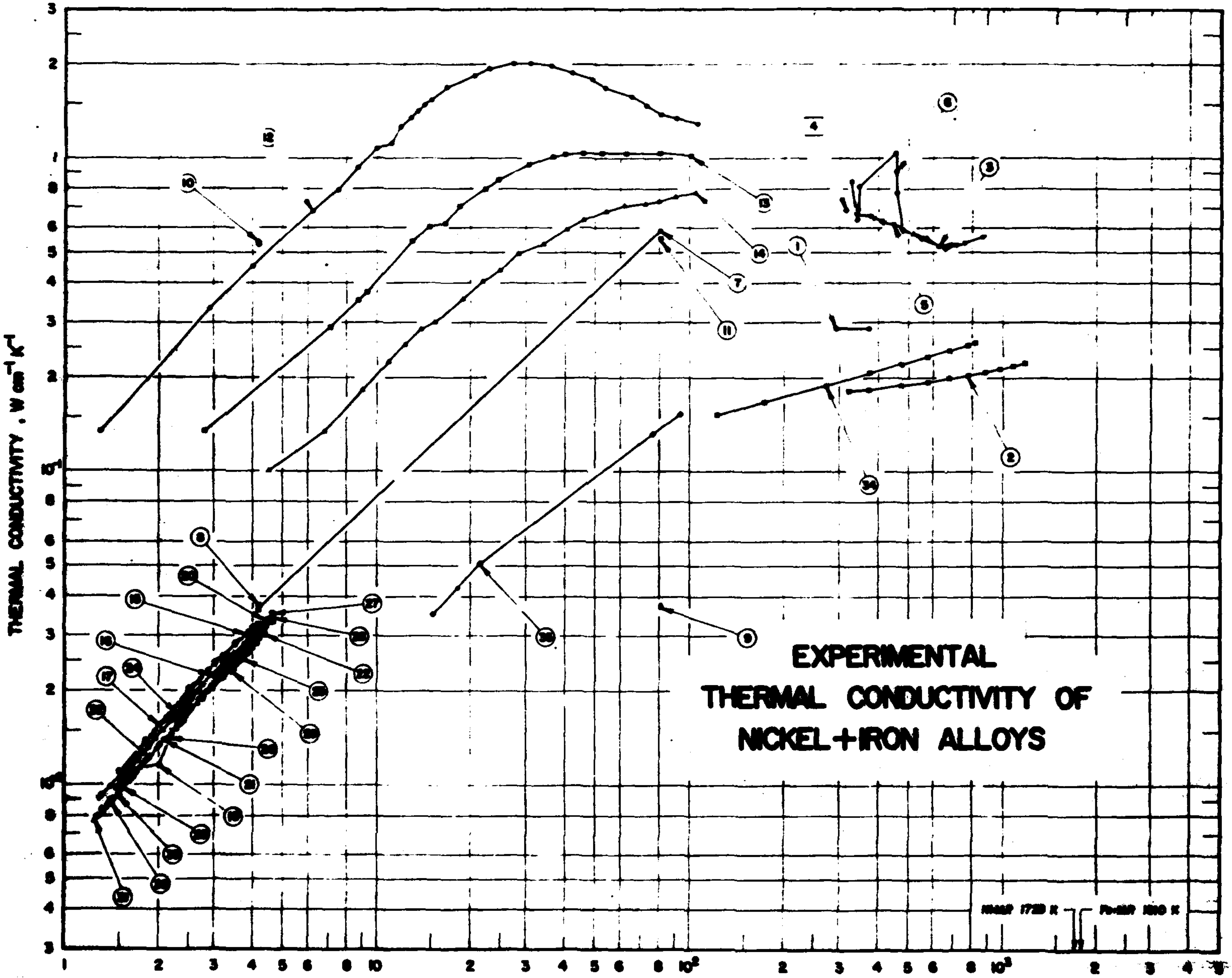
EXPERIMENTAL
THERMAL CONDUCTIVITY OF
NICKEL+IRON ALLOYS
THERMAL CONDUCTIVITY, W cm^{-1} K^{-1}
TEMPERATURE, K
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FIGURE

TABLE 26. THERMAL CONDUCTIVITY OF IRON + NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
1	98	Chari, M.S.R. and de Nobel, J.	1959	L	1.6-88	3703	Bal.	5.10	0.34 Mn, 0.16 Si, 0.11 C, 0.04 S, and 0.041 P; 7.5 mm diameter rod specimen; heated to 800 C and cooled in furnace.
2	122	Silverman, L.	1953	C	323-1173	42% Ni-iron	55.8	43.91	0.22 Mn, 0.050 C, and 0.003 S; annealed at 950 C; Advance used as comparative material.
3	96	Powell, R.W. and Hickman, M.J.	1939	C	273-423	Carbon steel; 1	Bal.	0.55	0.38 Mn, 0.06 Cu, 0.06 C, 0.039 As, 0.035 S, 0.03 Mo, 0.022 Cr, 0.017 P, 0.01 Si, and 0.001 Al; 1 in. diameter and 8 in. long; annealed at 930 C; density 7.871 g cm^{-3}; electrical resistivity 11.9, 14.6, 17.8, 21.1, and 24.9 $\mu\Omega$ cm at 0, 50, 100, 150, and 200 C, respectively.
4	96	Powell, R.W. and Hickman, M.J.	1939	C	273-573	Alloy steel; 9	Bal.	3.47	0.55 Mn, 0.325 C, 0.16 Si, 0.17 Cr, 0.085 Cu, 0.034 S, 0.032 P, 0.023 As, 0.04 Mo, 0.01 V, and 0.006 Al; annealed at 860 C; density 7.855 g cm^{-3}; electrical resistivity 25.5, 28.4, 31.5, 34.8, 38.5, 42.5, and 46.8 $\mu\Omega$ cm at 0, 50, 100, 150, 200, 250, and 300 C, respectively.
5	168	Powell, R.W.	1948	-	273-1473				The above specimen; thermal conductivity values calculated from measured electrical resistivity by the Wiedemann-Franz relation using extrapolated values of Lorenz function obtained from the previous thermal conductivity measurements.
6	98	Ingersoll, L.R., Hancock, O.F., Swartz, D.L., Smith, E.F., Thompson, C.G., Mahre, M.A., Frederickson, J.F. and Hubbard, D.R.	1920	L	330	144E	Bal.	1.07	<0.1 C; electrolytic.
7	98	Ingersoll, L.R., et al.	1920	L	330	144F	Bal.	1.93	<0.1 C; electrolytic.
8	98	Ingersoll, L.R., et al.	1920	L	330	144J	Bal.	7.06	<0.1 C; electrolytic.
9	98	Ingersoll, L.R., et al.	1920	L	330	157D	Bal.	10.20	<0.1 C; electrolytic.
10	98	Ingersoll, L.R., et al.	1920	L	330	144M	Bal.	13.11	<0.1 C; electrolytic.
11	98	Ingersoll, L.R., et al.	1920	L	330	146P	Bal.	19.21	<0.1 C; electrolytic.
12	98	Ingersoll, L.R., et al.	1920	L	330	166G	Bal.	22.11	<0.1 C; electrolytic; electrical resistivity reported as 38.7, 45.4, 53.4, 62.7, 72.5, 82.1, 106.3, and 111.6 $\mu\Omega$ cm at 273.2, 373.2, 473.2, 573.2, 673.2, 773.2, 873.2, and 973.2 K, respectively.
13	98	Ingersoll, L.R., et al.	1920	L	330	154S	Bal.	25.20	<0.1 C; electrolytic.
14	98	Ingersoll, L.R., et al.	1920	L	330	166C	Bal.	28.42	<0.1 C; electrolytic.
15	98	Ingersoll, L.R., et al.	1920	L	330	166L	Bal.	35.09	<0.1 C; electrolytic; electrical resistivity reported as 90.3, 100.0, 108.1, 115.2, 119.4, 123.2, 125.9, and 129.3 $\mu\Omega$ cm at 273.2, 373.2, 473.2, 573.2, 673.2, 773.2, 873.2, and 973.2 K, respectively.
16	98	Ingersoll, L.R., et al.	1920	L	330	166O	Bal.	47.08	<0.1 C; electrolytic; electrical resistivity reported as 44.2, 60.0, 75.6, 92.1, 103.3, 109.3, 112.3, and 114.0 $\mu\Omega$ cm at 273.2, 373.2, 473.2, 573.2, 673.2, 773.2, 873.2, and 973.2 K, respectively.
17	131	Ellis, W.C., Morgan, F.L. and Sager, G.F.	1928	P	305	Climax	Bal.	30.0	2.5 mm diameter and 25 mm long; density 8.01 g cm^{-3}; electrical conductivity 1.052 x 10^{4} Ω^{-1} cm^{-1} at 32 C; thermal conductivity value calculated from measured thermal diffusivity and specific heat capacity.

TABLE 26. THERMAL CONDUCTIVITY OF IRON + NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
18	103	Marue, H.	1926	C	446	Nickel steel	Bal.	3.41	0.45 C; steel used as comparative material.
19	102	Watson, T.W. and Robinson, H.E.	1961	L	125-263	AISI 2515	94.076	4.91	0.52 Mn, 0.33 Si, and 0.14 C; specimen about 2.54 cm in diameter and about 37 cm long; furnished by International Nickel Co.; normalized at 1144.3 K, tempered at 866.5 K.
20	102	Watson, T.W. and Robinson, H.E.	1961	L	163-483	AISI 2515			The above specimen, run 2.
21	102	Watson, T.W. and Robinson, H.E.	1961	L	372-573	AISI 2515			The above specimen, run 3.
22	102	Watson, T.W. and Robinson, H.E.	1961	L	400-696	AISI 2515			The above specimen, run 4.
23	102	Watson, T.W. and Robinson, H.E.	1961	L	423-908	AISI 2515			The above specimen, run 5.
24	101	Bäcklund, N.G.	1961	L	100-280	3		0.946	Original material supplied by Heraeus, Inc.; re-melted and rolled into bars with a cross-section of about 15 mm² and a length of 100 mm; after a short rolling, annealed at 1373 K for 2 hr in evacuated silica tubes, then rolled to final form and annealed at about 773 K for 10 hr; electrical resistivity 3.4, 7.9, and 12.9 μΩ cm at 90, 193, and 290 K, respectively.
25	101	Bäcklund, N.G.	1961	L	100-280	5		1.90	Similar to the above specimen; electrical resistivity 5.3, 9.5, and 15.1 μΩ cm at 90, 193, and 290 K, respectively.
26	102	Watson, T.W. and Robinson, H.E.	1961	L	123-813	High-perm-49	49.503	49.15	0.44 Mn, 0.54 Si, 0.09 Cr, and 0.035 C; specimen 2.54 cm in diameter and 37 cm long; supplied by International Nickel Co.; packed in powder and annealed in hydrogen 5 hr at 922.1 K, 5 hr at 1450 K; furnace cooled to 700 K; data presented as a smooth curve.
27	102	Watson, T.W. and Robinson, H.E.	1961	L	123-813	Invar	63.97	35.41	0.13 Si, 0.06 C, and 0.04 Cr; specimen 2.54 cm in diameter and 37 cm long; supplied by International Nickel Co.; annealed 30 min at 1102.6 K, water-quenched, air-cooled at 588.7 K for 1 hr and at 369.3 K for 48 hr; data presented as a smooth curve.
28	102	Watson, T.W. and Robinson, H.E.	1961	L	123-813	AISI 2315	95.483	3.46	0.54 Mn, 0.32 Si, and 0.16 C; specimen 2.54 cm in diameter and 37 cm long; supplied by International Nickel Co.; normalized at 1172.5 K and tempered at 866.5 K; data presented as a smooth curve.
29	102	Watson, T.W. and Robinson, H.E.	1961	L	123-813	1% Ni	97.984	1.04	0.56 Mn, 0.27 Si, and 0.126 C; specimen 2.54 cm in diameter and 37 cm long; supplied by International Nickel Co.; normalized at 1200 K, tempered at 866.5 K; presented as a smooth curve.
30	97, 165	Kohlhaas, R. and Kierspe, W.	1965	L	90-298	10 Ni 14		3.75	0.45 Mn, 0.32 Si, and 0.06 C; heat-treated in air at 850 C for 0.5 hr and at 600 C for 2 hr; electrical resistivity 16.76, 21.80, 22.80, 24.21, 25.52, 27.06, 28.36, 29.50, and 30.70 μΩ cm at -190, -70, -50, -25, 0, 20, 40, 60, and 80 C, respectively.
31	97, 165	Kohlhaas, R. and Kierspe, W.	1965	L	90-298	12 Ni 19		4.75	0.40 Mn, 0.35 Si, and 0.086 C; same heat-treatment as above; electrical resistivity 18.26, 23.43, 24.51, 25.96, 27.81, 28.78, 29.98, 31.19, and 32.43 μΩ cm at -190, -70, -50, -25, 0, 20, 40, 60, and 80 C, respectively.
32	164	Bungardt, K. and Spyra, W.	1965	L	293-973	Ni 36	Bal.	36.91	0.32 Mn, 0.012 P, 0.08 Al, 0.06 Si, 0.06 Mo, 0.05 Co, 0.02 C, and 0.008 S; cylindrical specimen; heat-treated in water at 1000 C for 24 hr; electrical resistivity 75.1, 86.8, 96.3, 101.7, 105.7, 109.0, 112.2, 115.0, 117.5, 119.7, 121.8, and 123.7 μΩ cm at 20, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, and 1100 C, respectively; smoothed values reported.

TABLE 36. THERMAL CONDUCTIVITY OF IRON + NICKEL ALLOYS — SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
33	89	Chari, M.S.R. and de Nobel, J.	1960	L	1.7-76	1287 I		11.39	0.93 Mn, 0.22 Si, and 0.18 C; 5.5 mm diameter rod specimen; heated to 800 C and cooled in furnace.
34	89	Chari, M.S.R. and de Nobel, J.	1960	L	1.7-76	1798 H		19.64	1.09 Mn and 0.43 C; 7.5 mm diameter rod specimen; same heat-treatment as the above specimen.
35	100	de Nobel, J.	1961	L	15-180	1287 D		1.92	0.72 Mn, 0.21 Si, and 0.14 C; 0.5 cm diameter and 4 cm long; heated to 800 C and cooled in furnace.
36	100	de Nobel, J.	1961	L	15-96	1449 A		31.4	0.82 Mn and 0.70 C; 0.5 cm diameter and 4 cm long; heated to 800 C and cooled in furnace.
37	100	de Nobel, J.	1961	L	15-87	3450-3		36.17	0.92 Mn, 0.69 S, and 0.16 C; 0.5 cm diameter and 4 cm long; heated to 1050 C and quenched in water.
38	165	Honda, K.	1918	E	303	2a		4.6	0.48 Cu, 0.31 Mn, 0.11 Si, 0.10 C, 0.028 P, 0.026 S, and 0.012 Co (calculated composition); 5 mm diameter and 20 cm long; prepared by melting together iron and nickel in a porcelain crucible, resulting alloy polished, forged, annealed, and filed to size; annealed at 900 C; electrical conductivity 3.62 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
39	165	Honda, K.	1918	E	303	2b			Same composition, dimensions, and fabrication method as the above specimen; cooled once to -190 C in liquid air; electrical conductivity 3.64 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
40	165	Honda, K.	1918	E	303	3a		9.2	0.67 Cu, 0.32 Mn, 0.11 C, 0.11 Si, 0.027 P, 0.025 S, and 0.024 Co (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 2.81 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
41	165	Honda, K.	1918	E	303	3b			Same composition, dimensions, and fabrication method as the above specimen; cooled once to -190 C in liquid air; electrical conductivity 2.76 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
42	165	Honda, K.	1918	E	303	4a		13.8	0.87 Cu, 0.32 Mn, 0.12 C, 0.12 Si, 0.035 Co, 0.025 P, and 0.025 S (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 2.65 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
43	165	Honda, K.	1918	E	303	4b			Same composition, dimensions, and fabrication method as the above specimen; cooled once to -190 C in liquid air; electrical conductivity 2.56 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
44	165	Honda, K.	1918	E	303	5a		16.5	1.06 Cu, 0.32 Mn, 0.12 C, 0.12 Si, 0.046 Co, 0.024 P, and 0.024 S (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 2.22 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
45	165	Honda, K.	1918	E	303	5b			Same composition, dimensions, and fabrication method as the above specimen; cooled once to -190 C in liquid air; electrical conductivity 2.42 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
46	165	Honda, K.	1918	E	303	6a		21.2	1.17 Cu, 0.32 Mn, 0.135 C, 0.12 Si, 0.06 Co, 0.023 P, and 0.024 S (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 2.01 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.

TABLE 36. THERMAL CONDUCTIVITY OF IRON + NICKEL ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
47	165	Honda, K.	1918	E	303	6b			Same composition, dimensions, and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 2.20 x $10^4\ \Omega^{-1}\ cm^{-1}$ 30 C.
48	165	Honda, K.	1918	E	303	7a		23.6	1.27 Cu, 0.32 Mn, 0.14 C, 0.12 Si, 0.061 Co, 0.024 S, and 0.022 P (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 1.82 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
49*	165	Honda, K.	1918	E	303	7b			Same composition, dimensions, and fabrication method as the above specimen; cooled once to -190 C in liquid air; electrical conductivity 2.33 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
50	165	Honda, K.	1918	E	303	9a		27.7	1.44 Cu, 0.32 Mn, 0.15 C, 0.12 Si, 0.071 Co, 0.023 S, and 0.021 P (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 1.07 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
51*	165	Honda, K.	1918	E	303	9b			Same composition, dimensions, and fabrication method as the above specimen; cooled once to -190 C in liquid air; electrical conductivity 2.40 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
52	165	Honda, K.	1918	E	303	10a		29.1	1.51 Cu, 0.32 Mn, 0.15 C, 0.12 Si, 0.075 Co, 0.023 S, and 0.021 P (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 1.62 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
53	165	Honda, K.	1918	E	303	10b			Same composition, dimensions, and fabrication method as the above specimen; cooled once to -190 C in liquid air; electrical conductivity 2.35 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
54	165	Honda, K.	1918	E	303	11a		30.5	1.56 Cu, 0.32 Mn, 0.155 C, 0.12 Si, 0.078 Co, 0.023 S, and 0.020 P (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 1.68 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
55	165	Honda, K.	1918	E	303	11b			Same composition, dimensions, and fabrication method as the above specimen; cooled once to -190 C in liquid air; electrical conductivity 1.95 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
56	165	Honda, K.	1918	E	303	12a		32.8	1.65 Cu, 0.33 Mn, 0.16 C, 0.12 Si, 0.084 Co, 0.023 S, and 0.019 P (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 1.61 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
57	165	Honda, K.	1918	E	303	12b			Similar to the above specimen except cooled once to -190 C in liquid air instead of annealing.
58	165	Honda, K.	1918	E	303	13a		36.9	1.83 Cu, 0.32 Mn, 0.17 C, 0.13 Si, 0.095 Co, 0.022 S, and 0.018 P (calculated composition); same dimensions and fabrication method as the above specimen; annealed at 900 C; electrical conductivity 1.[illegible] x $10^4\ \Omega^{-1}\ cm^{-1}$ at 30 C.
59	96	Powell, R.W. and Hickman, M.J.	1939	C	273-623	High-Ni steel; 14		28.37	0.80 Mn, 0.28 C, 0.15 Si, 0.030 Cu, 0.027 As, 0.012 Al, 0.009 P, 0.008 S, and trace Cr; 1 in. diameter and 8 in. long; heated to [illegible] C and cooled in water; electrical resistivity 84.0, 86.3, 89.9, 92.9, 95.9, 98.9, 102.0, and 104.8 $\mu\Omega$ cm at 0, 50, 100, 150, 200, 250, 300, and 350 C, respectively; iron used as comparative material.

* Not shown in figure.

TABLE 26. THERMAL CONDUCTIVITY OF IRON + NICKEL ALLOYS — SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
60	102	Watson, T.W. and Robinson, H.E.	1961	L	123-813	Low-exp-42	56.303	42.11	0.97 Mn, 0.16 Si, 0.09 Cr, and 0.085 C; specimen 2.54 cm in diameter and 37 cm long; supplied by International Nickel Co.; annealed for 30 min at 1088.7 K, furnace cooled; data presented as a smooth curve.
61	102	Watson, T.W. and Robinson, H.E.	1961	L	123-813	free cut Invar	62.233	35.84	0.81 Mn, 0.34 Si, 0.12 Cr, and 0.06 C; specimen 2.54 cm in diameter and 37 cm long; supplied by International Nickel Co.; annealed for 30 min at 1102.6 K, water quenched, and air cooled 1 hr at 588.7 K, then 48 hr at 369.3 K; data presented as a smooth curve.
62	102	Watson, T.W. and Robinson, H.E.	1961	L	123-813	9% Ni	90.29	8.56	0.77 Mn, 0.28 Si, and 0.10 C; specimen 2.54 cm in diameter and 37 cm long; supplied by International Nickel Co.; normalized at (1650 + 1450 F) (1172 + 1061 K), tempered at 888.7 K; data presented as a smooth curve.
63	97, 101	Kohlhaas, R. and Kierspe, W.	1965	L	88-297	X8 Ni19		8.35	0.74 Mn, 0.28 Si, 0.051 C, 0.016 P, and 0.009 N; heat-treated in air at 790 C for 0.5 hr and at 570 C for 3.5 hr; electrical resistivity 22.66, 26.20, 29.34, 30.96, 32.56, 33.96, 35.21, 36.46, and 37.70 μΩ cm at -190, -70, -50, -25, 0, 20, 40, 60, and 80 C, respectively.

TABLE 27. THERMAL CONDUCTIVITY OF NICKEL + IRON ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
1	98	Ingersoll, L.R.	1920	L	293, 373	166 Q	75.06		<0.1 C; prepared from 99.97 pure iron and high-purity nickel by forging; 0.98 cm in diameter and 5.1 to 6.7 cm long; electrical resistivity 23.4, 31.3, 40.0, 51.0, 62.0, 70.2, 75.0, and 78.3 μΩ cm at 0, 100, 200, 300, 400, 500, 600, and 700 C, respectively.
2	132	Silverman, L.	1953	C	323-1173		50.85	48.5	0.12 Mn, 0.024 C, and 0.003 S; annealed at 950 C; Advance (55 Cu, 45 Ni) used as comparative material.
3	108	Shelton, S.M. and Swanger, W.H.	1933	C	512-685	N.S. nickel, commercial	99⁺	0.6	0.14 Cu, 0.09 Mn, and 0.014 S; 2 cm in diameter and 15 cm long; lead used as comparative material.
4	108	Shelton, S.M. and Swanger, W.H.	1933	C	313.2	N.S. nickel, commercial			Similar to the above specimen.
5	108	Shelton, S.M. and Swanger, W.H.	1933	C	339-864	N.S. nickel, commercial			Similar to the above specimen except nickel used as comparative material.
6	106	Bell, I.P. and MacDonald, J.J.	1953	L	328-472	Nickel, commercial	99.4	0.2	0.1 Mg, 0.05 Co, 0.03 Sn, 0.026 C, 0.02 Si, 0.01 Cr, 0.01 Mn, 0.005 S, 0.003 Ti, and 0.002 each of Al and Pb; cylindrical specimen.
7	107	Berger, L. and Rivier, D.	1962	L	4.2, 80		85.2	14.8	0.2 cm diameter and 5.2 cm long; fused in an induction furnace under vacuo of 10^{-3} torr; the mixture of Ni and Fe supplied by Johnson-Matthey; cold-rolled, annealed at 1173 K for 2 hr, slowly cooled; electrical resistivity 3.78, 4.60, and 13.22 μΩ cm at 4.18, 80.5, and 292.7 K, respectively.
8	107	Berger, L. and Rivier, D.	1962	L	4.2				The above specimen measured in transverse magnetic fields ranging from 0.150 to 1.92 W m^{-2}.
9	107	Berger, L. and Rivier, D.	1962	L	80				The above specimen measured in transverse magnetic fields ranging from 0.373 to 1.92 W m^{-2}.
10	107	Berger, L. and Rivier, D.	1962	L	4.2				The above specimen measured in longitudinal magnetic fields ranging from 0.079 to 1.76 W m^{-2}.
11	107	Berger, L. and Rivier, D.	1962	L	80				The above specimen measured in longitudinal magnetic fields ranging from 0.051 to 1.41 W m^{-2}.
12	81	Farrell, T. and Greig, D.	1969	L	1.3-106			0.8	About 3 mm in diameter and 9 cm long; chill-cast under vacuum; annealed at 850 C for 15 hr; residual electrical resistivity 0.307 μΩ cm.
13	81	Farrell, T. and Greig, D.	1969	L	2.8-100			1.7	Similar to the above specimen except residual electrical resistivity 0.713 μΩ cm; electrical resistivity 7.99 μΩ cm at 0 C.
14	81	Farrell, T. and Greig, D.	1969	L	4.5-106			4.4	Similar to the above specimen except residual electrical resistivity 1.80 μΩ cm; electrical resistivity 9.84 μΩ cm at 0 C.
15	166	Yelon, W.B. and Berger, L.	1970	L	1.3-4.1	Permalloy	82	18	Calculated composition.
16	166	Yelon, W.B. and Berger, L.	1970	L	1.5-4.1	Permalloy	71	29	Calculated composition.
17	166	Yelon, W.B. and Berger, L.	1970	L	1.5-4.0	Permalloy			The above specimen measured in a longitudinal magnetic field of 0.781 T.
18*	166	Yelon, W.B. and Berger, L.	1970	L	1.5-4.0	Permalloy			The above specimen measured in a longitudinal magnetic field of 3.3 T.

*Not shown in figure.

TABLE 27. THERMAL CONDUCTIVITY OF NICKEL + IRON ALLOYS — SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
19	105	Yelon, W.B. and Berger, L.	1970	L	1.5-4.0	Permalloy			The above specimen measured in a longitudinal magnetic field of 5.94 T.
20	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.6-4.4			29.8	Prepared by fusing Johnson-Matthey metals in argon atmosphere, remelting and casting into 0.5 in. rods in helium, swaging to 0.3125 in. in diameter, homogenizing in hydrogen at 1200 C for 38 hr, cooling to 900 C in vacuum and annealing for 2 hr; grain size 0.1 ~ 0.5 mm; electrical resistivity 4.24 μΩ cm at 4.2 K; run 7.
21	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.5-4.4				The above specimen measured in a parallel magnetic field of 7.81 kG.
22	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.6-4.4				The above specimen measured in a parallel magnetic field of 33.00 kG.
23	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.6-4.4				The above specimen measured in a parallel magnetic field of 59.40 kG.
24	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.5-4.3				The above specimen, no magnetic field; run 8.
25	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.3-4.4				The above specimen measured in a parallel magnetic field of 7.81 kG.
26	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.5-4.4				The above specimen measured in a parallel magnetic field of 59.40 kG.
27	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.3-4.7			18.9	Same preparation method as the above specimen; grain size 0.1-0.5 mm; electrical resistivity 4.32 μΩ cm at 4.2 K; run 2.
28	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.3-4.6				The above specimen measured in a parallel magnetic field of 7.15 kG.
29	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.4-4.6				The above specimen measured in a parallel magnetic field of 59.40 kG.
30	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.3-4.6				The above specimen measured in a parallel magnetic field of 7.15 kG; run 3.
31	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.2-4.6				The above specimen measured in a parallel magnetic field of 33.00 kG.
32	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.3-4.6				The above specimen measured in the same magnetic field; run 4.
33	106, 177	Yelon, W.B. and Berger, L.	1970	L	1.3-4.6				The above specimen measured in a parallel magnetic field of 59.40 kG.
34	108	Watson, T.W. and Robinson, H.E.	1961	L	123-813	HyMu 80	79.24	15.283	0.71 Mn, 0.19 Si, 0.06 Cr, and 0.049 C; 2.54 cm diameter and 37 cm long; supplied by International Nickel Co.; powder packed in, annealed in hydrogen at 922 K (1200 F) for 5 hr and at 1450 K (2150 F) for 5 hr, furnace cooled to 700 K (800 F), then cooled in hydrogen; smoothed values reported.
35	109	de Nobel, J.	1951	L	15-93	5277	57.5		1.31 Mn, 0.34 C, and 0.14 Si; as forged.

4.10. Silver-Palladium Alloy System

The silver-palladium alloy system exhibits complete solid solubility and is analogous to the copper-nickel alloy system, but without the complications of ferromagnetic effects and with an electronic specific heat that is better behaved [109].

There are 32 sets of experimental data available for the thermal conductivity of this alloy system. However, of the 18 data sets available for Ag + Pd alloys listed in Table 29 and shown in Figure 41 six sets are merely single data points, and of the 14 sets for Pd + Ag alloys listed in Table 30 and shown in Figure 42 seven sets are single data points.

This alloy system is the most extensively studied among the noble metal-palladium alloy systems, but the only reliable experimental data on thermal conductivity are the low temperature measurements by Kemp, et al. [110] (Pd + Ag curves 6-8 and Ag + Pd curves 6-14), Tainsh and White [111] (Ag + Pd curves 16-18), and Fletcher and Greig [84] (Pd + Ag curves 11-14). The early measurements by Schulze [93] (Pd + Ag curves 1-5 and Ag + Pd curves 1-5) of the room temperature thermal conductivity of these alloys at intervals of 10% gave values that are considerably above the actual values in some cases. Even after correcting for the lattice component, the Lorenz ratios corresponding to Schulze's values for the 60, 70, and 80% Pd alloys are respectively 30, 44, and 35% greater than the classical value; it is unlikely that band structure effects could cause such large Lorenz ratios in these alloys at 298 K. Further evidence that Schulze's values are unreliable is that he used the same method to measure the thermal conductivity of gold-palladium alloys, and that interpolation between his values for his 30 and 40% Pd specimens yields a value which is more than 25% greater than that obtained by Laubitz and van der Meer [85] for a specimen containing 35% Pd. On the other hand, the more recent measurements by Zolotukhin [112] at somewhat higher temperatures on specimens containing 25 and 50% Ag (Pd + Ag curves 9 and 10 and Ag + Pd curve 15) appear to be too low, in the second instance by approximately 25%.

This alloy system is one of the few in which the thermal conductivity has been measured over a very wide range of compositions from liquid helium temperatures to 100 K. The measurements by Kemp, et al. were undertaken to obtain fundamental information about the electron-phonon interaction, in particular to see whether electrons interact with lattice waves of all polarizations, to determine the dependence of the interaction on electron concentration and to deduce, by interpolation between these and similar measurements on silver-cadmium alloys, the contribution of the electron-phonon interaction to the lattice thermal resistivity of silver. The study revealed the cusp-like behavior of the low temperature lattice conductivity as a function of composition, as discussed in Section 2 on Theoretical Background, and led to additional measurements by Tainsh and White following further

annealing at higher temperatures to determine whether or not this behavior was caused by the locking in of dislocations by solute atoms. While the cusp-like behavior persisted, it was found that an increase in the annealing temperature from 883 K to 1213 K resulted in increases of 30% or more in the lattice thermal conductivities of these specimens at liquid helium temperatures.

A comparison of the values calculated from eqs. (12) and (35) in the region above the lattice component maximum with the experimental values of Kemp, et al. revealed that the calculated values for the silver-rich alloys were too low, the total conductivity by as much as 8% and the lattice component by as much as 25%. It was found that both the total and lattice thermal conductivities could be brought into good agreement with the experimental values for all compositions from 2 to 30% Pd by increasing the value of the lattice thermal conductivity of silver by 50%. Although such an increase does not require unreasonable values for the Debye temperature or the Grüneisen parameter in the equation used to estimate the lattice thermal conductivity of the elements, it raises considerable doubt as to the reliability of such estimates. While the separation of the electronic and lattice components of very dilute alloys at temperatures above that of the maximum of the lattice component involves some uncertainty, a 50% error in the lattice component is unlikely, although excellent agreement was obtained for the lattice conductivities of both 2 and 5% Pd alloys, it was decided, in view of the conflicting evidence, not to report even provisional values for the lattice thermal conductivity of the dilute silver-rich alloys. In addition, while the measurements of Tainsh and White established that, in the region below its maximum, the lattice thermal conductivity of well-annealed samples is substantially greater than the values obtained from the first set of measurements, these later measurements were limited to temperatures below 10 K and to compositions of 2, 5, and 10% Pd and could, therefore, only serve as a rough guide for correcting the values of the lattice component obtained from measurements on specimens annealed at 883 K; accordingly, the values for the silver-rich alloys at temperatures below the maximum are provisional.

The lattice thermal conductivity of the palladium-rich alloys of this system was investigated by Fletcher and Greig, who measured the thermal conductivity of specimens containing 5, 10, 15, and 20% Ag from liquid helium temperatures to about 100 K. Their study showed that the strong electron-phonon interactions in these alloys greatly reduces the low temperature lattice thermal conductivity, causing its maximum to occur at much higher temperatures than in the silver-rich alloys. The increase in the temperature of the maximum of the lattice component is even greater than that shown in their graph because, at the higher temperatures, the method used to separate the electronic and lattice components yields values of the latter which are below the true values by an amount which increases with temperature, so that the lattice components of these alloys are still increasing at 100 K. This is consistent with the 100 K temperature of the maximum deduced from the measurements

by Kemp, et al. on a specimen containing 30% Ag. Since the measurements on the Pd-rich alloys did not extend to temperatures above those of the lattice thermal conductivity maxima, the values of the lattice component in this region were obtained by smoothly joining plots of the values deduced from measurements to those calculated from eq. (35).

The recommended values for k, k_e, and k_g are tabulated in Table 28 for 25 alloy compositions covering the full range of temperature from 4 to 1200 K for most cases. These values are for well-annealed alloys. The values for k are also shown in Figures 39 and 40. The values of residual electrical resistivity for the alloys are also given in Table 28. The uncertainties of the k values are stated in a footnote to Table 28, while the uncertainties of the k_e and k_g values are indicated by their being designated as recommended or provisional values. The ranges of uncertainties of recommended and provisional values are less than ±15% and between ±15 and ±30%, respectively.

TABLE 28. RECOMMENDED THERMAL CONDUCTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Ag: 99.50% (99.49 At.%) Pd: 0.50% (0.51 At.%)			
ρ_o = 0.2400 μΩ cm			
T	k	k_e	k_g
4	0.449*	0.407	0.0415‡
6	0.698*	0.611	0.0865‡
8	0.949*	0.814	0.135‡
10	1.20*	1.02	0.180‡
15	1.78*	1.53	0.246‡
20	2.33*	2.04	0.285‡
25	2.65*	2.35	0.298‡
30	2.84*	2.54	0.300‡
40	3.03*	2.73	0.295‡
50	3.04*		
60	2.96*		
70	3.00*		
80	3.07*		
90	3.10*		
100	3.19*		
150	3.45*		
200	3.59*		
250	3.74*		
273	3.78*		
300	3.82*		
350	3.88*		
400	3.90*		
500	3.91*		
600	3.90*		
700	3.84*		
800	3.81*		
900	3.74*		
1000	3.67*		
1100	3.60*		
1200	3.55*		

Ag: 99.00% (98.99 At.%) Pd: 1.00% (1.01 At.%)			
ρ_o = 0.4900 μΩ cm			
T	k	k_e	k_g
4	0.230*	0.199	0.0310‡
6	0.365*	0.299	0.0655‡
8	0.505*	0.399	0.106‡
10	0.644*	0.499	0.145‡
15	0.963*	0.748	0.215‡
20	1.25*	0.997	0.254‡
25	1.47*	1.20	0.272‡
30	1.67*	1.39	0.276‡
40	1.96*	1.69	0.272‡
50	2.11*		
60	2.18*		
70	2.26*		
80	2.35*		
90	2.44*		
100	2.52*		
150	2.87*		
200	3.12*		
250	3.27*		
273	3.33*		
300	3.41*		
350	3.50*		
400	3.57*		
500	3.63*		
600	3.69*		
700	3.67*		
800	3.67*		
900	3.62*		
1000	3.57*		
1100	3.51*		
1200	3.46*		

Ag: 97.00% (96.96 At.%) Pd: 3.00% (3.04 At.%)			
ρ_o = 1.390 μΩ cm			
T	k	k_e	k_g
4	0.0963‡	0.0703	0.0260‡
6	0.159‡	0.105	0.0535‡
8	0.228‡	0.141	0.0870‡
10	0.300‡	0.176	0.124‡
15	0.453‡	0.264	0.189‡
20	0.571‡	0.352	0.219‡
25	0.665‡	0.433	0.232‡
30	0.748‡	0.513	0.235‡
40	0.892‡	0.661	0.231‡
50	1.01		
60	1.09		
70	1.18		
80	1.25		
90	1.33		
100	1.41		
150	1.76		
200	2.02*		
250	2.24*		
273	2.33*		
300	2.43*		
350	2.57*		
400	2.69*		
500	2.89*		
600	3.03*		
700	3.12*		
800	3.18*		
900	3.21*		
1000	3.22*		
1100	3.22*		
1200	3.22*		

Ag: 95.00% (94.93 At.%) Pd: 5.00% (5.07 At.%)			
ρ_o = 2.260 μΩ cm			
T	k	k_e	k_g
4	0.0634‡	0.0432	0.0202‡
6	0.109‡	0.0649	0.0445‡
8	0.160‡	0.0865	0.0735‡
10	0.212‡	0.108	0.104‡
15	0.319‡	0.162	0.157‡
20	0.405‡	0.216	0.189‡
25	0.467‡	0.262	0.205‡
30	0.521‡	0.311	0.210‡
40	0.612‡	0.404	0.208‡
50	0.685		
60	0.750		
70	0.811		
80	0.877		
90	0.938		
100	0.996		
150	1.27		
200	1.51*		
250	1.71*		
273	1.79*		
300	1.88*		
350	2.04*		
400	2.18*		
500	2.41*		
600	2.58*		
700	2.72*		
800	2.83*		
900	2.89*		
1000	2.93*		
1100	2.96*		
1200	2.98*		

† Uncertainties of the total thermal conductivity, k, are as follows:

99.50 Ag - 0.50 Pd: ±10% below 40 K, ±7% between 40 and 300 K, and ±10% above 300 K.
99.00 Ag - 1.00 Pd: ±15% below 40 K and ±10% above 40 K.
97.00 Ag - 3.00 Pd: ±15% below 40 K and ±10% above 40 K.
95.00 Ag - 5.00 Pd: ±15% below 40 K and ±10% above 40 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 28. RECOMMENDED THERMAL CONDUCTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (continued) †

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Ag: 90.00% (89.88 At.%) Pd: 10.00% (10.12 At.%)				Ag: 85.00% (84.82 At.%) Pd: 15.00% (15.18 At.%)				Ag: 80.00% (79.78 At.%) Pd: 20.00% (20.22 At.%)				Ag: 75.00% (74.74 At.%) Pd: 25.00% (25.26 At.%)			
ρ_0 = 4.46 μΩ cm				ρ_0 = 6.46 μΩ cm				ρ_0 = 8.41 μΩ cm				ρ_0 = 10.60 μΩ cm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0364‡	0.0219	0.0145‡	4	0.0299*‡	0.0151	0.0148‡	4	0.0270‡	0.0116	0.0154‡	4	0.0253*‡	0.00922	0.0161‡
6	0.0662‡	0.0329	0.0333‡	6	0.0553*‡	0.0227	0.0326‡	6	0.0518‡	0.0174	0.0344‡	6	0.0483*‡	0.0138	0.0345‡
8	0.100‡	0.0438	0.0562‡	8	0.0853*‡	0.0303	0.0550‡	8	0.0812‡	0.0232	0.0580‡	8	0.0764*‡	0.0184	0.0580‡
10	0.135‡	0.0578	0.0775‡	10	0.119*‡	0.0378	0.0810‡	10	0.112‡	0.0290	0.0825‡	10	0.107*‡	0.0230	0.0840‡
15	0.201‡	0.0822	0.119‡	15	0.182*‡	0.0567	0.125‡	15	0.165‡	0.0436	0.121‡	15	0.159*‡	0.0346	0.124‡
20	0.253‡	0.110	0.143‡	20	0.224*‡	0.0756	0.148‡	20	0.200‡	0.0581	0.142‡	20	0.192*‡	0.0461	0.146‡
25	0.292‡	0.135	0.157‡	25	0.251*‡	0.0931	0.158‡	25	0.224‡	0.0717	0.152‡	25	0.213*‡	0.0569	0.156‡
30	0.324‡	0.161	0.163‡	30	0.272*‡	0.111	0.161‡	30	0.241‡	0.0856	0.155‡	30	0.223*‡	0.0680	0.155‡
40	0.374‡	0.213	0.161‡	40	0.301*‡	0.147	0.154‡	40	0.263‡	0.113	0.150‡	40	0.238*‡	0.0901	0.148‡
50	0.417	0.261	0.156	50	0.326*	0.181	0.145	50	0.281	0.140	0.141	50	0.248*	0.112	0.136
60	0.454	0.307	0.147	60	0.351*	0.215	0.136	60	0.298	0.167	0.131	60	0.259*	0.133	0.126
70	0.491	0.352	0.139	70	0.375*	0.248	0.127	70	0.316	0.193	0.123	70	0.271*	0.154	0.117
80	0.527	0.396	0.131	80	0.400*	0.281	0.119	80	0.333	0.219	0.114	80	0.285*	0.175	0.110
90	0.565	0.441	0.124	90	0.427*	0.314	0.113	90	0.352	0.245	0.107	90	0.299*	0.195	0.104
100	0.602	0.485	0.117	100	0.452*	0.346	0.106	100	0.371	0.270	0.101	100	0.314*	0.216	0.0975
150	0.780	0.687	0.0930	150	0.581*	0.497	0.0840	150	0.472	0.392	0.0800	150	0.393*	0.316	0.0770
200	0.943*	0.866	0.0775	200	0.706*	0.636	0.0700	200	0.573*	0.506	0.0670	200	0.475*	0.410	0.0645
250	1.10*	1.03	0.0665	250	0.827*	0.766	0.0610	250	0.671*	0.613	0.0580	250	0.556*	0.500	0.0560
273	1.16*	1.10	0.0627	273	0.881*	0.823	0.0575	273	0.716*	0.661	0.0545	273	0.593*	0.540	0.0530
300	1.24	1.18	0.0586	300	0.942*	0.888	0.0539	300	0.766	0.715	0.0511	300	0.635*	0.586	0.0494
350	1.38*	1.32	0.0526	350	1.05*	1.00	0.0487	350	0.858*	0.812	0.0463	350	0.711*	0.667	0.0448
400	1.50*	1.45	0.0479	400	1.16*	1.11	0.0444	400	0.946*	0.904	0.0424	400	0.782*	0.741	0.0411
500	1.72*	1.68	0.0406	500	1.35*	1.31	0.0380	500	1.11*	1.07	0.0364	500	0.922*	0.886	0.0364
600	1.91*	1.88	0.0354	600	1.52*	1.49	0.0333	600	1.26*	1.23	0.0320	600	1.05*	1.02	0.0313
700	2.07*	2.04	0.0313	700	1.68*	1.65	0.0297	700	1.39*	1.36	0.0287	700	1.17*	1.14	0.0281
800	2.21*	2.18	0.0282	800	1.82*	1.80	0.0268	800	1.52*	1.50	0.0260	800	1.29*	1.26	0.0255
900	2.32*	2.30	0.0256	900	1.93*	1.91	0.0245	900	1.62*	1.60	0.0238	900	1.38*	1.36	0.0234
1000	2.41*	2.38	0.0235	1000	2.02*	2.00	0.0226	1000	1.71*	1.69	0.0220	1000	1.45*	1.43	0.0216
1100	2.47*	2.45	0.0217	1100	2.10*	2.08	0.0209	1100	1.78*	1.76	0.0204	1100	1.53*	1.51	0.0201
1200	2.53*	2.51	0.0201	1200	2.16*	2.14	0.0195	1200	1.84*	1.82	0.191	1200	1.60*	1.58	0.0188

† Uncertainties of the total thermal conductivity, k, are as follows:
90.00 Ag - 10.00 Pd: ±15% below 40 K and ±10% above 40 K.
85.00 Ag - 15.00 Pd: ±20% below 40 K and ±10% above 40 K.
80.00 Ag - 20.00 Pd: ±20% below 40 K and ±10% above 40 K.
75.00 Ag - 25.00 Pd: ±20% below 40 K and ±10% above 40 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 28. RECOMMENDED THERMAL CONDUCTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Ag: 70.00% (69.71 At.%) Pd: 30.00% (30.29 At.%)			
ρ_0 = 13.01 μΩcm			
T	k	k_e	k_g
4	0.0241‡	0.00781	0.0163‡
6	0.0472‡	0.0113	0.0359‡
8	0.0755‡	0.0150	0.0605‡
10	0.102‡	0.0188	0.0835‡
15	0.154‡	0.0282	0.126‡
20	0.186‡	0.0376	0.148‡
25	0.201‡	0.0464	0.155‡
30	0.212‡	0.0555	0.156‡
40	0.221‡	0.0736	0.147‡
50	0.227	0.0913	0.136
60	0.236	0.110	0.126
70	0.243	0.126	0.117
80	0.252	0.143	0.109
90	0.263	0.161	0.102
100	0.275	0.178	0.0965
150	0.338	0.261	0.0765
200	0.404*	0.340	0.0640
250	0.471*	0.415	0.0555
273	0.501*	0.449	0.0520
300	0.534	0.486	0.0484
350	0.599*	0.556	0.0430
400	0.661*	0.621	0.0403
500	0.781*	0.746	0.0349
600	0.891*	0.860	0.0306
700	0.998*	0.970	0.0277
800	1.10*	1.07	0.0252
900	1.19*	1.16	0.0232
1000	1.26*	1.24	0.0215
1100	1.32*	1.30	0.0200
1200	1.39*	1.37	0.0187

Ag: 65.00% (64.69 At.%) Pd: 35.00% (35.31 At.%)			
ρ_0 = 15.62 μΩcm			
T	k	k_e	k_g
4	0.0231*‡	0.00628	0.0168‡
6	0.0439*‡	0.00938	0.0345‡
8	0.0690*‡	0.0125	0.0565‡
10	0.0945*‡	0.0156	0.0789‡
15	0.144*‡	0.0235	0.121‡
20	0.175*‡	0.0313	0.144‡
25	0.191*‡	0.0387	0.152‡
30	0.201*‡	0.0463	0.155‡
40	0.210*‡	0.0614	0.149‡
50	0.214*	0.0763	0.138
60	0.216*	0.0909	0.125
70	0.220*	0.106	0.114
80	0.227*	0.120	0.107
90	0.235*	0.134	0.101
100	0.245*	0.149	0.0960
150	0.294*	0.219	0.0750
200	0.349*	0.286	0.0625
250	0.403*	0.349	0.0540
273	0.428*	0.377	0.0510
300	0.457*	0.409	0.0479
350	0.511*	0.468	0.0436
400	0.563*	0.523	0.0400
500	0.664*	0.629	0.0346
600	0.758*	0.727	0.0307
700	0.846*	0.818	0.0276
800	0.926*	0.901	0.0252
900	0.997*	0.974	0.0231
1000	1.06*	1.04	0.0215
1100	1.12*	1.10	0.0200
1200	1.18*	1.16	0.0188

Ag: 60.00% (59.67 At.%) Pd: 40.00% (40.33 At.%)			
ρ_0 = 18.44 μΩcm			
T	k	k_e	k_g
4	0.0222‡	0.00530	0.0169‡
6	0.0410‡	0.00795	0.0330‡
8	0.0646‡	0.0106	0.0540‡
10	0.0881‡	0.0132	0.0749‡
15	0.134‡	0.0199	0.114‡
20	0.163‡	0.0265	0.136‡
25	0.179‡	0.0328	0.146‡
30	0.189‡	0.0393	0.150‡
40	0.197‡	0.0521	0.145‡
50	0.200	0.0648	0.135
60	0.201	0.0772	0.124
70	0.201	0.0896	0.115
80	0.205	0.102	0.107
90	0.214	0.114	0.100
100	0.221	0.127	0.0940
150	0.260	0.186	0.0740
200	0.304*	0.242	0.0620
250	0.350*	0.296	0.0540
273	0.371*	0.320	0.0510
300	0.396	0.348	0.0479
350	0.441*	0.397	0.0435
400	0.484*	0.444	0.0400
500	0.567*	0.532	0.0347
600	0.643*	0.613	0.0307
700	0.715*	0.687	0.0278
800	0.780*	0.754	0.0252
900	0.837*	0.813	0.0232
1000	0.889*	0.867	0.0216
1100	0.938*	0.917	0.0201
1200	0.984*	0.965	0.0189

Ag: 55.00% (54.66 At.%) Pd: 45.00% (45.34 At.%)			
ρ_0 = 21.56 μΩcm			
T	k	k_e	k_g
4	0.0212*‡	0.00453	0.0167‡
6	0.0382*‡	0.00680	0.0314‡
8	0.0576*‡	0.00907	0.0485‡
10	0.0778*‡	0.0113	0.0665‡
15	0.118*‡	0.0170	0.101‡
20	0.144*‡	0.0227	0.121‡
25	0.162*‡	0.0280	0.134‡
30	0.173*‡	0.0335	0.139‡
40	0.183*‡	0.0445	0.138‡
50	0.183*	0.0553	0.128‡
60	0.185*	0.0659	0.119
70	0.187*	0.0764	0.111
80	0.191*	0.0870	0.104
90	0.195*	0.0974	0.0975
100	0.200*	0.108	0.0920
150	0.232*	0.158	0.0740
200	0.269*	0.206	0.0630
250	0.305*	0.251	0.0540
273	0.323*	0.272	0.0510
300	0.343*	0.295	0.0482
350	0.380*	0.336	0.0438
400	0.416*	0.376	0.0403
500	0.482*	0.447	0.0349
600	0.543*	0.512	0.0310
700	0.599*	0.571	0.0279
800	0.651*	0.626	0.0255
900	0.701*	0.677	0.0236
1000	0.750*	0.728	0.0218
1100	0.798*	0.778	0.0204
1200	0.846*	0.827	0.0191

† Uncertainties of the total thermal conductivity, k, are as follows:
70.00 Ag - 30.00 Pd: ±20% below 40 K and ±10% above 40 K.
65.00 Ag - 35.00 Pd: ±20% below 40 K and ±10% above 40 K.
60.00 Ag - 40.00 Pd: ±20% below 40 K and ±10% above 40 K.
55.00 Ag - 45.00 Pd: ±20% below 40 K and ±10% above 40 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 28. RECOMMENDED THERMAL CONDUCTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (continued) †

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Ag: 50.00% (49.66 At.%) Pd: 50.00% (50.34 At.%)				Ag: 45.00% (44.66 At.%) Pd: 55.00% (55.34 At.%)				Ag: 40.00% (39.67 At.%) Pd: 60.00% (60.33 At.%)				Ag: 35.00% (34.69 At.%) Pd: 65.00% (65.31 At.%)			
ρ_0 = 27.44 μΩcm				ρ_0 = 36.50 μΩcm				ρ_0 = 40.15 μΩcm				ρ_0 = 39.40 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0197‡	0.00356	0.0161‡	4	0.0174*‡	0.00268	0.0147‡	4	0.0150*‡	0.00243	0.0126‡	4	0.0132*‡	0.00248	0.0107‡
6	0.0347‡	0.00534	0.0294‡	6	0.0292*‡	0.00402	0.0252‡	6	0.0243*‡	0.00365	0.0206‡	6	0.0200*‡	0.00372	0.0163‡
8	0.0502‡	0.00712	0.0431‡	8	0.0411*‡	0.00536	0.0356‡	8	0.0335*‡	0.00487	0.0286‡	8	0.0268*‡	0.00496	0.0218‡
10	0.0654‡	0.00890	0.0565‡	10	0.0527*‡	0.00669	0.0460‡	10	0.0423*‡	0.00609	0.0362‡	10	0.0332*‡	0.00620	0.0270‡
15	0.0974‡	0.0134	0.0840‡	15	0.0755*‡	0.0100	0.0655‡	15	0.0611*‡	0.00913	0.0520‡	15	0.0476*‡	0.00930	0.0383‡
20	0.118‡	0.0178	0.100‡	20	0.914*‡	0.0134	0.0780‡	20	0.0757*‡	0.0122	0.0635‡	20	0.0599*‡	0.0124	0.0475‡
25	0.131‡	0.0220	0.109‡	25	0.103*‡	0.0166	0.0860‡	25	0.0866*‡	0.0151	0.0715‡	25	0.0703*‡	0.0153	0.0550‡
30	0.141‡	0.0264	0.115‡	30	0.111*‡	0.0199	0.0910‡	30	0.0946*‡	0.0181	0.0765‡	30	0.0793*‡	0.0183	0.0610‡
40	0.152‡	0.0349	0.117‡	40	0.123*‡	0.0264	0.0965‡	40	0.106*‡	0.0240	0.0820‡	40	0.0933*‡	0.0243	0.0690‡
50	0.157	0.0434	0.114	50	0.131*‡	0.0327	0.0985‡	50	0.115*‡	0.0298	0.0850‡	50	0.104*‡	0.0302	0.0740‡
60	0.162	0.0518	0.110	60	0.137*‡	0.0390	0.0980‡	60	0.122*‡	0.0356	0.0865‡	60	0.113*‡	0.0359	0.0770‡
70	0.165	0.0596	0.105	70	0.141*	0.0452	0.0960	70	0.128*‡	0.0414	0.0870‡	70	0.121*‡	0.0417	0.0790‡
80	0.168	0.0680	0.0995	80	0.144*	0.0514	0.0930	80	0.133*‡	0.0469	0.0860‡	80	0.127*‡	0.0474	0.0795‡
90	0.171	0.0760	0.0945	90	0.148*	0.0576	0.0900	90	0.138*	0.0526	0.0850	90	0.133*‡	0.0531	0.0800‡
100	0.175	0.0841	0.0905	100	0.151*	0.0637	0.0870	100	0.142*	0.0582	0.0835	100	0.138*‡	0.0585	0.0800‡
150	0.198*	0.123	0.0745	150	0.167*	0.0935	0.0735	150	0.159*	0.0859	0.0730	150	0.158*	0.0854	0.0730
200	0.222*	0.159	0.0630	200	0.186*	0.122	0.0635	200	0.175*	0.111	0.0640	200	0.177*	0.111	0.0655
250	0.250*	0.194	0.0556	250	0.206*	0.150	0.0560	250	0.193*	0.136	0.0570	250	0.195*	0.136	0.0590
273	0.263*	0.210	0.0525	273	0.216*	0.162	0.0535	273	0.202*	0.148	0.0543	273	0.204*	0.147	0.0565
300	0.276	0.228	0.0480	300	0.226*	0.176	0.0499	300	0.212	0.161	0.0513	300	0.214*	0.161	0.0532
350	0.304*	0.259	0.0445	350	0.249*	0.204	0.0454	350	0.233*	0.186	0.0467	350	0.233*	0.185	0.0484
400	0.330	0.289	0.0409	400	0.272*	0.231	0.0418	400	0.255*	0.212	0.0429	400	0.253*	0.208	0.0445
500	0.381	0.346	0.0354	500	0.318*	0.281	0.0362	500	0.297*	0.260	0.372	500	0.293*	0.254	0.0385
600	0.429*	0.398	0.0314	600	0.362*	0.330	0.0321	600	0.339*	0.306	0.0330	600	0.334*	0.299	0.0342
700	0.477*	0.449	0.0284	700	0.407*	0.378	0.0290	700	0.381*	0.352	0.0296	700	0.375*	0.344	0.0306
800	0.524*	0.498	0.0259	800	0.453*	0.426	0.0264	800	0.424*	0.397	0.0272	800	0.417*	0.389	0.0281
900	0.573*	0.549	0.0239	900	0.499*	0.474	0.0244	900	0.468*	0.443	0.0250	900	0.461*	0.435	0.0259
1000	0.622*	0.600	0.0221	1000	0.545*	0.522	0.0226	1000	0.511*	0.488	0.0232	1000	0.505*	0.481	0.0240
1100	0.672*	0.651	0.0207	1100	0.591*	0.570	0.0211	1100	0.556*	0.535	0.0217	1100	0.551*	0.529	0.0224
1200	0.723*	0.704	0.0194	1200	0.637*	0.617	0.0198	1200	0.602*	0.582	0.0204	1200	0.598*	0.577	0.0211

† Uncertainties of the total thermal conductivity, k, are as follows:
50.00 Ag - 50.00 Pd: ±15% below 40 K, and ±10% above 40 K.
45.00 Ag - 55.00 Pd: ±15% below 60 K, and ±10% above 40 K.
40.00 Ag - 60.00 Pd: ±15% below 80 K, and ±10% above 80 K.
35.00 Ag - 65.00 Pd: ±15% below 100 K, and ±10% above 100 K.

‡ Provisional value.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 28. RECOMMENDED THERMAL CONDUCTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Ag: 30.00% (29.71 At.%) Pd: 70.00% (70.29 At.%)				Ag: 25.00% (24.74 At.%) Pd: 75.00% (75.26 At.%)				Ag: 20.00% (19.78 At.%) Pd: 80.00% (80.22 At.%)				Ag: 15.00% (14.83 At.%) Pd: 85.00% (85.17 At.%)			
ρ_0 = 35.11 μΩcm				ρ_0 = 29.95 μΩcm				ρ_0 = 24.13 μΩcm				ρ_0 = 18.15 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.0108	0.00278	0.00800	4	0.00906*	0.00326	0.00580	4	0.00805	0.00405	0.00400	4	0.00807	0.00538	0.00269
6	0.0163	0.00418	0.0121	6	0.0140*	0.00489	0.00910	6	0.0127	0.00606	0.00665	6	0.0127	0.00806	0.00465
8	0.0218	0.00557	0.0162	8	0.0190*	0.00653	0.0125	8	0.0175	0.00810	0.00940	8	0.0177	0.0108	0.00685
10	0.0273	0.00696	0.0203	10	0.0241*	0.00816	0.0159	10	0.0225	0.0101	0.0124	10	0.0228	0.0135	0.00925
15	0.0399	0.0104	0.0295	15	0.0362*	0.0122	0.0240	15	0.0350	0.0152	0.0198	15	0.0359	0.0202	0.0157
20	0.0516	0.0139	0.0377	20	0.0480*	0.0163	0.0317	20	0.0472	0.0202	0.0270	20	0.0496	0.0270	0.0226
25	0.0618	0.0170	0.0448	25	0.0583*	0.0198	0.0385	25	0.0583	0.0243	0.0340	25	0.0618	0.0323	0.0295
30	0.0712	0.0203	0.0509	30	0.0681*	0.0236	0.0445	30	0.0690	0.0289	0.0401	30	0.0748	0.0383	0.0365
40	0.0866	0.0266	0.0600	40	0.0855*	0.0310	0.0545	40	0.0889	0.0379	0.0510	40	0.0979	0.0499	0.0480
50	0.0995	0.0332	0.0663	50	0.0995*	0.0383	0.0612	50	0.105	0.0465	0.0585	50	0.117	0.0608	0.0565
60	0.110	0.0394	0.0706	60	0.111*	0.0452	0.0660	60	0.119	0.0548	0.0645	60	0.134	0.0711	0.0625
70	0.119	0.0455	0.0735	70	0.121*	0.0521	0.0685	70	0.131	0.0629	0.0680	70	0.147	0.0809	0.0665
80	0.127	0.0516	0.0750	80	0.131*	0.0589	0.0718	80	0.142	0.0708	0.0710	80	0.160	0.0906	0.0695
90	0.134	0.0577	0.0760	90	0.138*	0.0657	0.0720	90	0.152	0.0787	0.0730	90	0.172	0.100	0.0720
100	0.140	0.0637	0.0760	100	0.145*	0.0723	0.0725	100	0.159	0.0864	0.0740	100	0.183	0.109	0.0740
150	0.165	0.0918	0.0735	150	0.170*	0.0975	0.0725	150	0.197*	0.121	0.0760	150	0.227*	0.149	0.0780
200	0.187*	0.119	0.0675	200	0.201*	0.133	0.0685	200	0.226*	0.153	0.0725	200	0.261*	0.184	0.0770
250	0.207*	0.145	0.0615	250	0.224*	0.160	0.0635	250	0.250*	0.182	0.0680	250	0.289*	0.215	0.0740
273	0.215*	0.156	0.0590	273	0.234*	0.172	0.0615	273	0.261*	0.195	0.0655	273	0.301*	0.229	0.0720
300	0.226	0.170	0.0556	300	0.246*	0.187	0.0589	300	0.274	0.211	0.0632	300	0.314*	0.245	0.0693
350	0.245*	0.195	0.0506	350	0.266*	0.213	0.0535	350	0.296*	0.239	0.0573	350	0.338*	0.275	0.0628
400	0.265*	0.219	0.0465	400	0.287*	0.238	0.0491	400	0.319*	0.266	0.0526	400	0.362*	0.305	0.0575
500	0.305*	0.265	0.0402	500	0.329	0.287	0.0425	500	0.364*	0.319	0.0454	500	0.409*	0.360	0.0494
600	0.346*	0.310	0.0367	600	0.373*	0.335	0.0376	600	0.410*	0.370	0.0401	600	0.454*	0.411	0.0435
700	0.387*	0.355	0.0321	700	0.417*	0.384	0.0338	700	0.455*	0.419	0.0360	700	0.499*	0.460	0.0390
800	0.429*	0.401	0.0283	800	0.461*	0.430	0.0306	800	0.499*	0.466	0.0327	800	0.541*	0.506	0.0353
900	0.474*	0.447	0.0270	900	0.504*	0.476	0.0283	900	0.543*	0.513	0.0300	900	0.585*	0.552	0.0324
1000	0.518*	0.493	0.0250	1000	0.547*	0.521	0.0262	1000	0.586*	0.558	0.0278	1000	0.627*	0.597	0.0299
1100	0.564*	0.541	0.0233	1100	0.593*	0.569	0.0245	1100	0.630*	0.604	0.0259	1100	0.669*	0.641	0.0277
1200	0.613*	0.591	0.0219	1200	0.640*	0.617	0.0229	1200	0.675*	0.651	0.0242	1200	0.712*	0.686	0.0259

† Uncertainties of the total thermal conductivity, k, are as follows:
30.00 Ag - 70.00 Pd: ±10% below 100 K, ±7% between 100 and 300 K, and ±10% above 300 K.
25.00 Ag - 75.00 Pd: ±10% below 150 K, ±7% between 150 and 300 K, and ±10% above 300 K.
20.00 Ag - 80.00 Pd: ±10% below 150 K, ±7% between 150 and 300 K, and ±10% above 300 K.
15.00 Ag - 85.00 Pd: ±10% below 150 K, ±7% between 150 and 300 K, and ±10% above 300 K.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 28. RECOMMENDED THERMAL CONDUCTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Ag: 10.00% (9.88 At.%) Pd: 90.00% (90.12 At.%)				Ag: 5.00% (4.94 At.%) Pd: 95.00% (95.06 At.%)				Ag: 3.00% (2.96 At.%) Pd: 97.00% (97.04 At.%)				Ag: 1.00% (0.99 At.%) Pd: 99.00% (99.01 At.%)			
ρ_0 = 12.16 μΩcm				ρ_0 = 6.08 μΩcm				ρ_0 = 3.670 μΩcm				ρ_0 = 1.270 μΩcm			
T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g	T	k	k_e	k_g
4	0.00955	0.00804	0.00151	4	0.0170	0.0161	0.000900	4		0.0266		4		0.0769	
6	0.0151	0.0121	0.00301	6	0.0261	0.0241	0.00199	6		0.0399		6		0.115	
8	0.0209	0.0161	0.00480	8	0.0355	0.0321	0.00342	8		0.0533		8		0.154	
10	0.0270	0.0201	0.00685	10	0.0454	0.0402	0.00515	10		0.0666		10		0.192	
15	0.0428	0.0301	0.0127	15	0.0708	0.0603	0.0105	15		0.0999		15		0.289	
20	0.0596	0.0402	0.0194	20	0.0974	0.0804	0.0170	20		0.133		20		0.385	
25	0.0742	0.0481	0.0261	25	0.120	0.0955	0.0240	25		0.153		25		0.416	
30	0.0898	0.0566	0.0332	30	0.143	0.112	0.0311	30		0.177		30		0.459	
40	0.119	0.0728	0.0460	40	0.184	0.139	0.0452	40		0.214		40		0.499	
50	0.144	0.0875	0.0560	50	0.217	0.159	0.0579	50		0.237		50		0.495	
60	0.165	0.101	0.0640	60	0.245	0.177	0.0682	60		0.254		60		0.482	
70	0.184	0.114	0.0700	70	0.269	0.192	0.0770	70		0.269		70		0.471	
80	0.200	0.126	0.0740	80	0.292	0.208	0.0842	80		0.285		80		0.472	
90	0.216	0.138	0.0780	90	0.312	0.222	0.0898	90		0.301		90		0.475	
100	0.230	0.149	0.0810	100	0.330	0.236	0.0940	100		0.313		100		0.479	
150	0.283*	0.195	0.0875	150	0.393*	0.287	0.106	150		0.358		150		0.482	
200	0.321*	0.233	0.0875	200	0.433*	0.325	0.108	200		0.389		200		0.490	
250	0.349*	0.265	0.0840	250	0.459*	0.356	0.103	250		0.417		250		0.502	
273	0.362*	0.280	0.0815	273	0.470*	0.370	0.0995	273		0.422		273		0.510	
300	0.376	0.297	0.0786	300	0.483*	0.387	0.0958	300	0.553*	0.445	0.108	300	0.651*	0.523	0.127
350	0.400*	0.329	0.0711	350	0.504*	0.419	0.0858	350	0.572*	0.477	0.0958	350	0.663*	0.552	0.111
400	0.424*	0.360	0.0649	400	0.525*	0.447	0.0777	400	0.589*	0.503	0.0862	400	0.675*	0.576	0.0989
500	0.469*	0.414	0.0554	500	0.563*	0.497	0.0654	500	0.624*	0.553	0.0718	500	0.705*	0.624	0.0808
600	0.514*	0.466	0.0485	600	0.602*	0.546	0.0566	600	0.661*	0.599	0.0615	600	0.740*	0.671	0.0682
700	0.555*	0.511	0.0432	700	0.641*	0.591	0.0499	700	0.699*	0.645	0.0538	700	0.777*	0.718	0.0591
800	0.595*	0.556	0.0390	800	0.676*	0.632	0.0446	800	0.733*	0.685	0.0479	800	0.814*	0.762	0.0521
900	0.636*	0.600	0.0366	900	0.713*	0.673	0.0404	900	0.769*	0.726	0.0431	900	0.852*	0.806	0.0465
1000	0.679*	0.642	0.0327	1000	0.746*	0.709	0.0369	1000	0.799*	0.760	0.0392	1000	0.885*	0.843	0.0421
1100	0.715*	0.684	0.0303	1100	0.779*	0.745	0.0339	1100	0.831*	0.795	0.0359	1100	0.920*	0.881	0.0384
1200	0.759*	0.727	0.0282	1200	0.812*	0.781	0.0314	1200	0.862*	0.829	0.0332	1200	0.955*	0.920	0.0353

† Uncertainties of the total thermal conductivity, k, are as follows:
10.00 Ag - 90.00 Pd: ±10%.
5.00 Ag - 95.00 Pd: ±10%.
3.00 Ag - 97.00 Pd: ±10%.
1.00 Ag - 99.00 Pd: ±10%.

* In temperature range where no experimental thermal conductivity data are available.

TABLE 28. RECOMMENDED THERMAL CONDUCTIVITY OF SILVER–PALLADIUM ALLOY SYSTEM (continued)†

[Temperature, T, K; Thermal Conductivity, k, W cm^{-1} K^{-1}; Electronic Thermal Conductivity, k_e, W cm^{-1} K^{-1}; Lattice Thermal Conductivity, k_g, W cm^{-1} K^{-1}]

Ag: 0.50% (.49 At.%) Pd: 99.50% (99.51 At.%)			
ρ_0 = 0.000 μΩcm			
T	k	k_e	k_g
4		0.148	
6		0.222	
8		0.296	
10		0.370	
15		0.555	
20		0.740	
25		0.763	
30		0.743	
40		0.757	
50		0.705	
60		0.642	
70		0.601	
80		0.577	
90		0.572	
100		0.563	
150		0.534	
200		0.529	
250		0.534	
273		0.540	
300	0.685*	0.551	0.134
350	0.694*	0.577	0.117
400	0.709*	0.606	0.103
500	0.712*	0.648	0.0637
600	0.767*	0.697	0.0704
700	0.803*	0.742	0.0607
800	0.838*	0.785	0.0533
900	0.878*	0.831	0.0475
1000	0.912*	0.869	0.0429
1100	0.949*	0.910	0.0391
1200	0.986*	0.952	0.0339

† Uncertainties of the total thermal conductivity, k, are as follows:
0.50 Ag – 99.50 Pd: ±10%.

* In temperature range where no experimental thermal conductivity data are available.

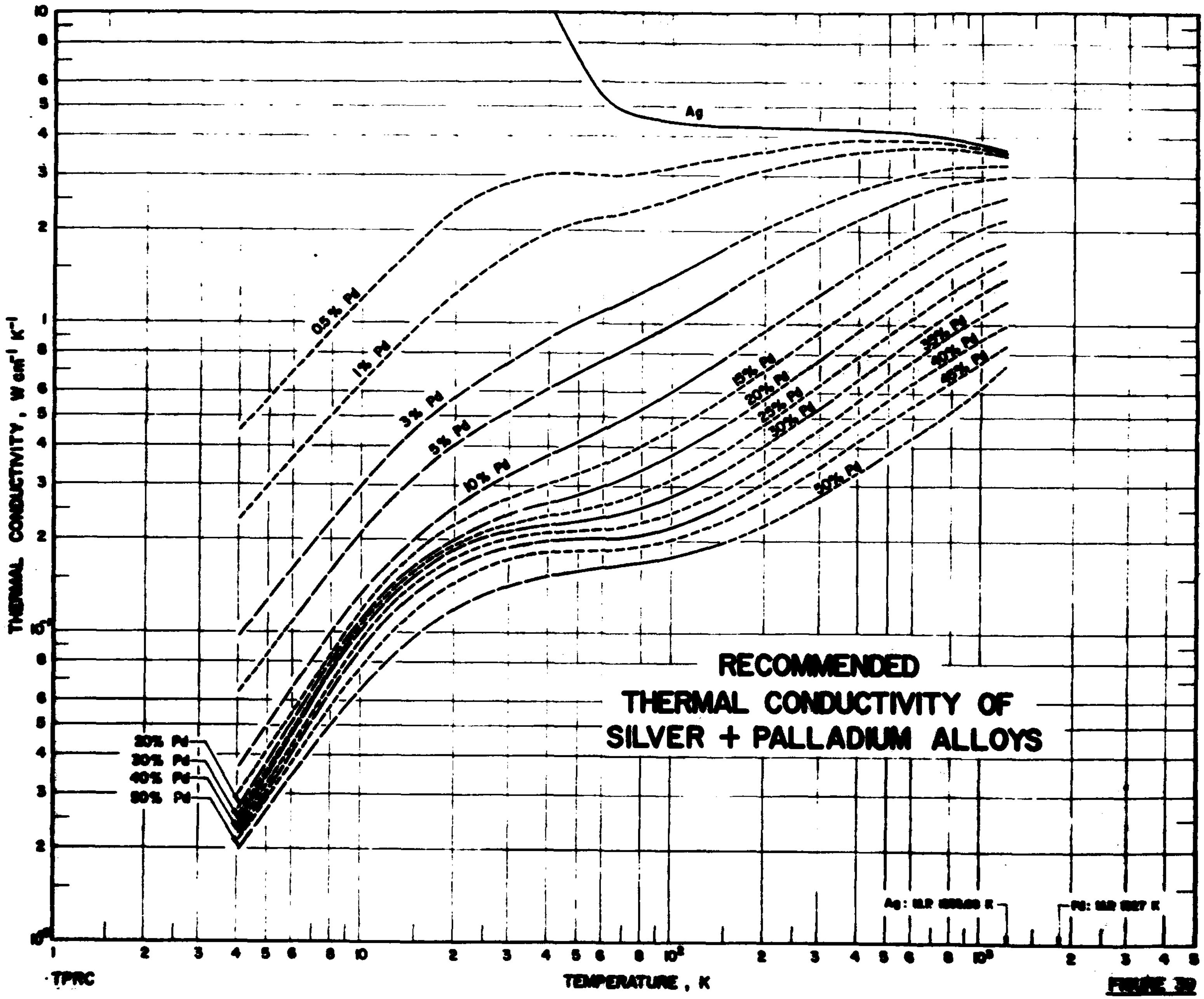
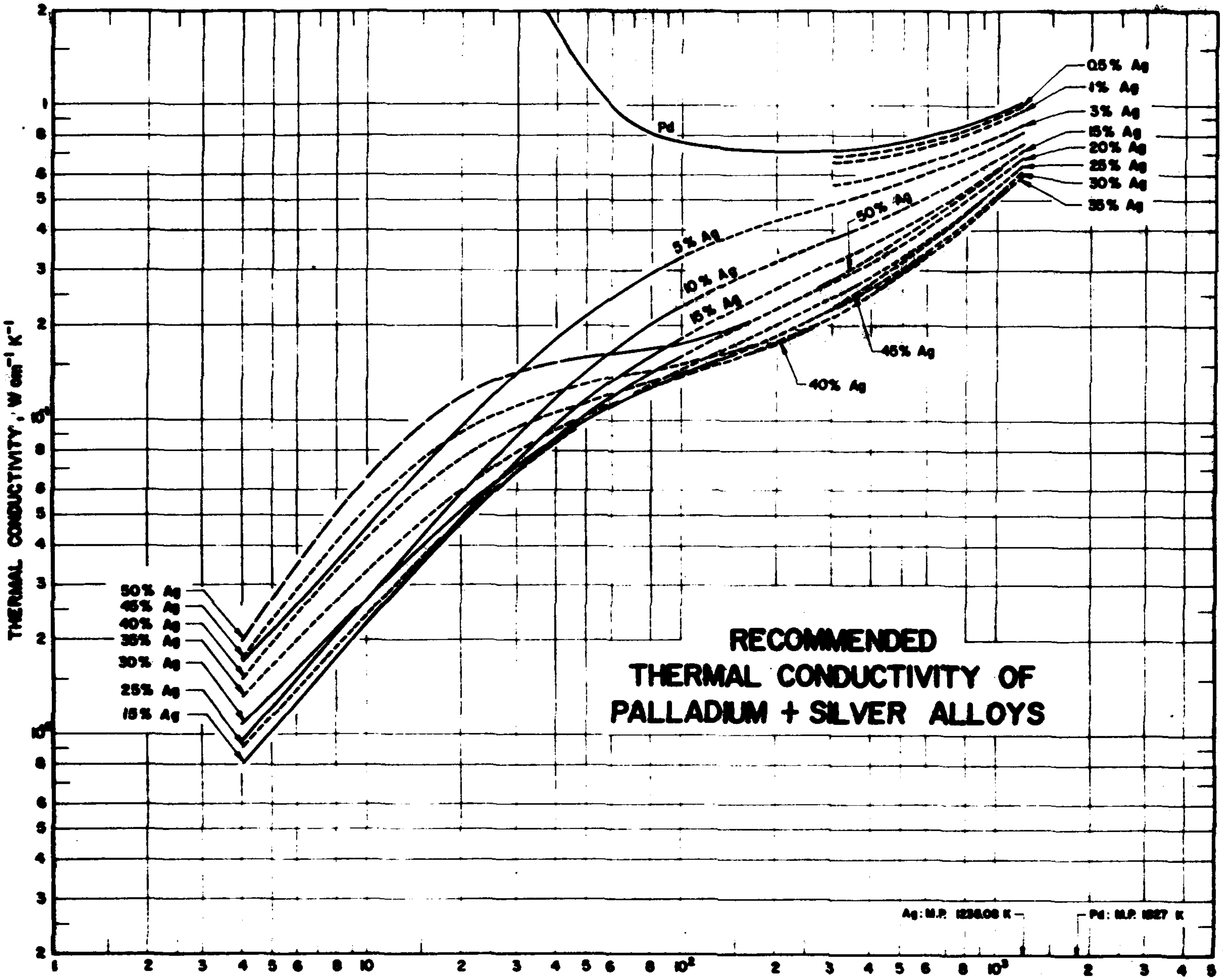

RECOMMENDED
THERMAL CONDUCTIVITY OF
SILVER + PALLADIUM ALLOYS
THERMAL CONDUCTIVITY, W cm⁻¹ K⁻¹
TEMPERATURE, K
Ag
0.5 % Pd
1% Pd
3% Pd
5% Pd
10% Pd
15% Pd
20% Pd
25% Pd
30% Pd
35% Pd
40% Pd
45% Pd
50% Pd
20% Pd
30% Pd
40% Pd
50% Pd
TPRC

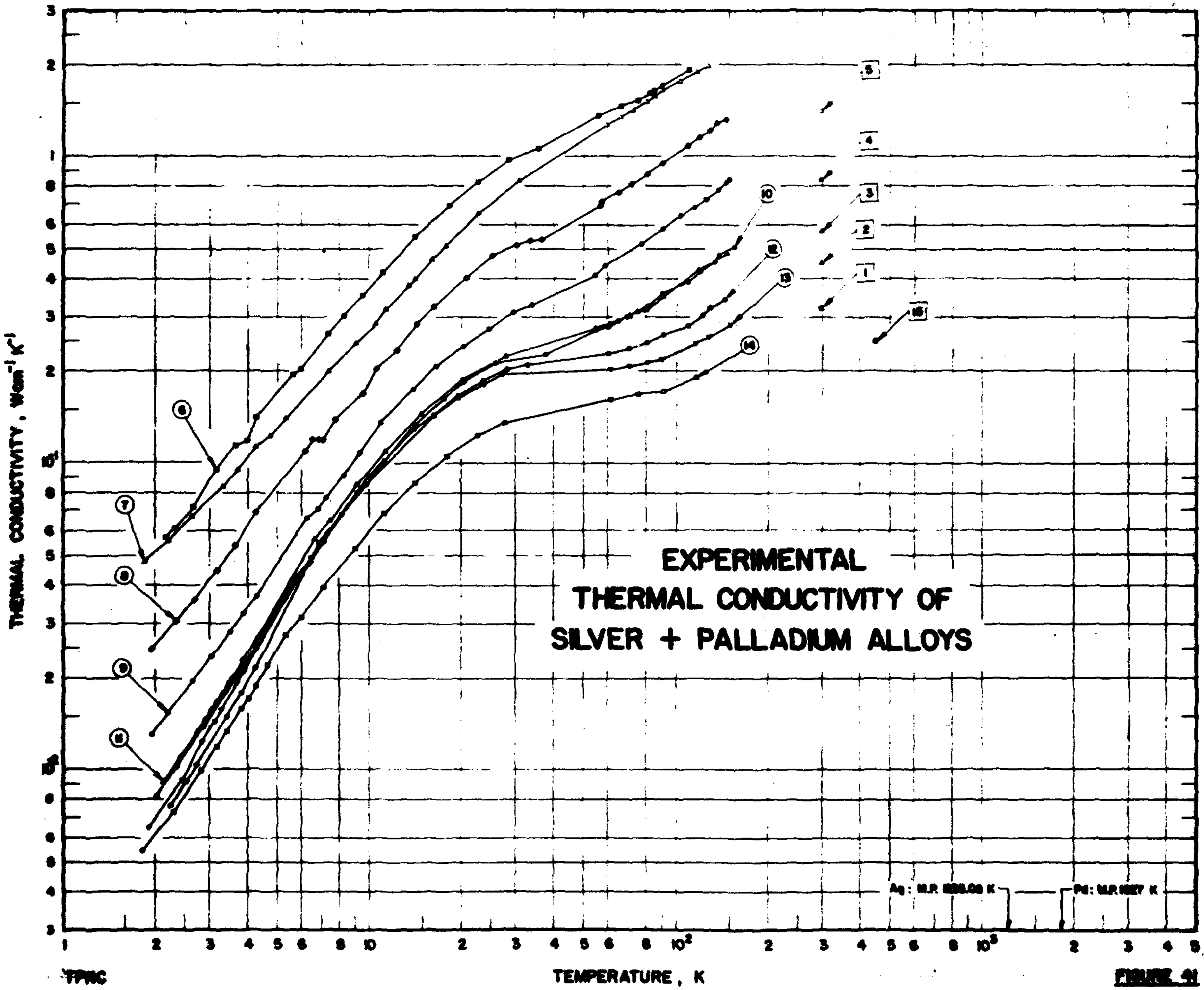
FIGURE 39



TPRC

TEMPERATURE, K

FIGURE 40



TPRC

FIGURE 41

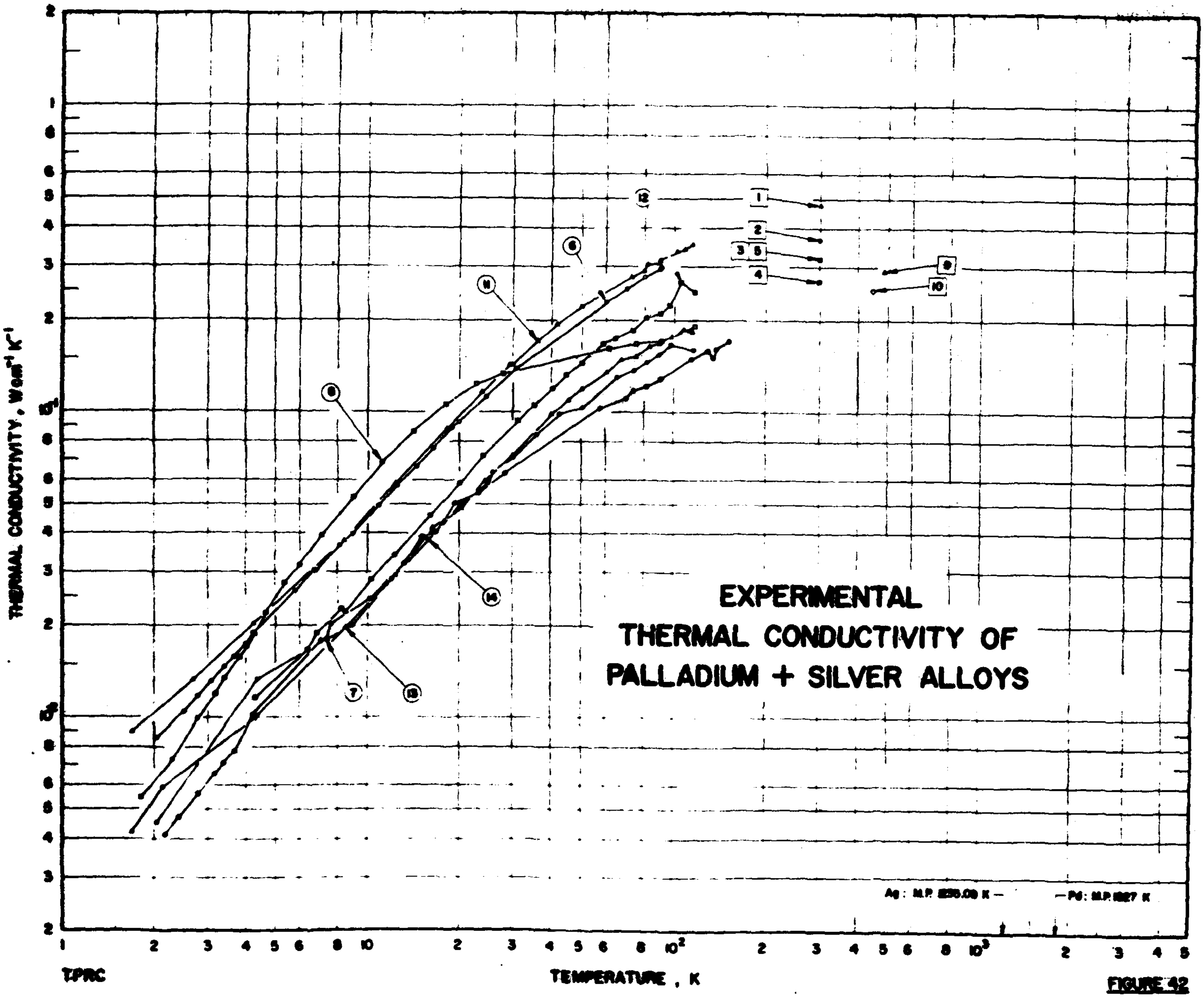

EXPERIMENTAL
THERMAL CONDUCTIVITY OF
PALLADIUM + SILVER ALLOYS
THERMAL CONDUCTIVITY, W cm⁻¹ K⁻¹
TEMPERATURE , K
TPRC
Ag : M.P. 1235.08 K
Pd : M.P. 1827 K

FIGURE 42

TABLE 29. THERMAL CONDUCTIVITY OF SILVER + PALLADIUM ALLOYS — SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Pd	Composition (continued), Specifications, and Remarks
1	93	Schulze, F.A.	1911	E	298.2		50	50	1 mm wire specimen obtained from Firma Heraeus; electrical conductivity 3.03 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
2	93	Schulze, F.A.	1911	E	296.2		60	40	1 mm wire specimen obtained from Firma Heraeus; electrical conductivity 4.56 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
3	93	Schulze, F.A.	1911	E	298.2		70	30	1 mm wire specimen obtained from Firma Heraeus; electrical conductivity 6.43 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
4	93	Schulze, F.A.	1911	E	298.2		80	20	1 mm wire specimen obtained from Firma Heraeus; electrical conductivity 9.47 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
5	93	Schulze, F.A.	1911	E	298.2		90	10	1 mm wire specimen obtained from Firma Heraeus; electrical conductivity 16.14 x $10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
6	110	Kemp, W.R.G., Klemens, P.G., Sreedhar, A.K. and White, G.K.	1956	L	2.2-112		97.95	2.05	Rod specimen supplied by Johnson, Matthey and Co., Ltd.; annealed at 610 C; residual electrical resistivity 0.89 μΩ cm; electrical resistivity 2.52 μΩ cm at 293 K.
7	110	Kemp, W.R.G., et al.	1956	L	1.8-128				The above specimen; strained; residual electrical resistivity 0.94 μΩ cm; electrical resistivity 2.54 μΩ cm at 293 K.
8	110	Kemp, W.R.G., et al.	1956	L	1.9-147		95.01	4.99	Rod specimen supplied by Johnson, Matthey and Co., Ltd.; annealed at 610 C; residual electrical resistivity 2.20 μΩ cm; electrical resistivity 3.91 μΩ cm at 293 K.
9	110	Kemp, W.R.G., et al.	1956	L	2.0-150		90.22	9.78	Rod specimen supplied by Johnson, Matthey and Co., Ltd.; annealed at 650 C; residual electrical resistivity 4.15 μΩ cm; electrical resistivity 6.0 μΩ cm at 293 K.
10	110	Kemp, W.R.G., et al.	1956	L	2.3-187		80.14	19.86	Rod specimen supplied by Johnson, Matthey and Co., Ltd.; annealed at 650 C.
11	110	Kemp, W.R.G., et al.	1956	L	2.1-147		80.14	19.86	Rod specimen supplied by Johnson, Matthey and Co., Ltd.; annealed at 800 C; residual electrical resistivity 8.45 μΩ cm; electrical resistivity 10.0 μΩ cm at 293 K.
12	110	Kemp, W.R.G., et al.	1956	L	2.2-145		70.67	29.33	Rod specimen supplied by Johnson, Matthey and Co., Ltd.; annealed at 800 C; residual electrical resistivity 12.78 μΩ cm; electrical resistivity 14.66 μΩ cm at 293 K.
13	110	Kemp, W.R.G., et al.	1956	L	1.9-151		60.33	39.67	Rod specimen supplied by Johnson, Matthey and Co., Ltd.; annealed at 880 C; residual electrical resistivity 18.10 μΩ cm; electrical resistivity 21.1 μΩ cm at 293 K.
14	110	Kemp, W.R.G., et al.	1956	L	1.9-117		50.34	49.66	Rod specimen supplied by Johnson, Matthey and Co., Ltd.; annealed at 880 C; residual electrical resistivity 27.7 μΩ cm; electrical resistivity 27.7 μΩ cm at 293 K.
15	112	Zeletskhin, G.F.	1966	L	448.2		50.34	49.66	0.66 cm^2 in cross-section and 1.36 cm long.

TABLE 29. THERMAL CONDUCTIVITY OF SILVER + PALLADIUM ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION (continued)

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Pd	Composition (continued), Specifications, and Remarks
16	111	Tainsh, R.J. and White, G.K.	1962	L	2.2-7.9		97.95	2.05	The specimen for curve no. 6 has been reannealed at 940 C in an effort to ensure that dislocation density is reduced to a minimum; rod specimen of about 6 cm long and 3 to 5 mm in diameter; electrical resistivity reported as 0.962, 1.372, and 2.612 $\mu\Omega$ cm at 0, 90, and 293 K, respectively.
17	111	Tainsh, R.J. and White, G.K.	1962	L	2.1-8.3		95.01	4.99	The specimen for curve no. 8 has been reannealed at 940 C in an effort to ensure that dislocation density is reduced to a minimum; rod specimen of about 6 cm long and 3 to 5 mm in diameter; electrical resistivity reported as 2.28, 2.68, and 3.87 $\mu\Omega$ cm at 0, 90, and 293 K, respectively.
18	111	Tainsh, R.J. and White, G.K.	1962	L	2.3-7.9		90.22	9.78	The specimen for curve no. 9 has been reannealed to 940 C in an effort to ensure that dislocation density is reduced to a minimum; rod specimen of about 6 cm long and 3 to 5 mm in diameter; electrical resistivity reported as 4.37, 4.78, and 6.01 $\mu\Omega$ cm at 0, 90, and 293 K, respectively.

TABLE 30. THERMAL CONDUCTIVITY OF PALLADIUM + SILVER ALLOYS -- SPECIMEN CHARACTERIZATION AND MEASUREMENT INFORMATION

Cur. No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Ag	Composition (continued), Specifications, and Remarks
1	93	Schulze, F.A.	1911	E	298.2		90	10	1 mm thick wire specimen obtained from Heraeus Co.; electrical conductivity $4.71 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
2	93	Schulze, F.A.	1911	E	298.2		80	20	1 mm thick wire specimen obtained from Heraeus Co.; electrical conductivity $3.21 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
3	93	Schulze, F.A.	1911	E	298.2		70	30	1 mm thick wire specimen obtained from Heraeus Co.; electrical conductivity $2.56 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
4	93	Schulze, F.A.	1911	E	298.2		60	40	1 mm thick wire specimen obtained from Heraeus Co.; electrical conductivity $2.38 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
5	93	Schulze, F.A.	1911	E	298.2		50	50	1 mm thick wire specimen obtained from Heraeus Co.; electrical conductivity $3.03 \times 10^4\ \Omega^{-1}\ cm^{-1}$ at 25 C.
6	110	Kemp, W.R.G., Klemens, P.G., Sreedhar, A.K. and White, G.K.	1956	L	2.1-92		95	5	Rod specimen supplied by Johnson, Matthey and Co., Ltd.; annealed at 880 C; residual electrical resistivity 5.81 $\mu\Omega$ cm; electrical resistivity 16.8 $\mu\Omega$ cm at 293 K.
7	110	Kemp, W.R.G., et al.	1956	L	2.2-152		70	30	Similar to the above specimen except residual electrical resistivity 35.6 $\mu\Omega$ cm and electrical resistivity 40.9 $\mu\Omega$ cm at 293 K.
8	110	Kemp, W.R.G., et al.	1956	L	1.8-117		50	50	Similar to the above specimen except residual electrical resistivity 27.7 $\mu\Omega$ cm and electrical resistivity 30.5 $\mu\Omega$ cm at 293 K.
9	112	Zolotukhin, G.E.	1956	L	486.7		75	25	Cylindrical specimen.
10	112	Zolotukhin, G.E.	1966	L	448.2		50	50	Cylindrical specimen.
11	84	Fletcher, R. and Greig, D.	1967	L	1.7-117			4.84	Calculated compositon from atomic percent; specimen lent by International Nickel Ltd.; annealed at 700 C for 24 hrs previously; outgassed at 500 C for 4-5 hrs; residual electrical resistivity reported as 5.92 $\mu\Omega$; original data obtained through private communication with author.
12	84	Fletcher, R. and Greig, D.	1967	L	4.3-118			9.85	Similar to the above specimen except the residual electrical resistivity reported as 12.18 $\mu\Omega$ cm.
13	84	Fletcher, R. and Greig, D.	1967	L	1.7-115			15.05	Similar to the above specimen except the residual electrical resistivity reported as 18.0 $\mu\Omega$ cm.
14	84	Fletcher, R. and Greig, D.	1967	L	2.1-116			20.53	Similar to the above specimen except the residual electrical resistivity reported as 24.5 $\mu\Omega$ cm.

5. CONCLUSIONS AND RECOMMENDATIONS

As evidenced by the available experimental thermal conductivity data presented in this work for the ten binary alloy systems selected as those most extensively investigated, it is clear that, still, for most of these alloy systems serious gaps exist for either the compositional or the temperature dependence or both and that most of the available data are widely divergent and subject to large uncertainty. The recommended self-consistent thermal conductivity values that cover the full ranges of composition and temperature are therefore very useful and valuable.

The recommended values are based upon both the critically evaluated, analyzed, and synthesized experimental data and the values calculated using the semitheoretical methods developed in this work.

It is thought that the reliability of the methods for the calculation of the thermal conductivity of binary alloys has been sufficiently tested with selected key sets of reliable data on alloys in the various binary alloy systems. The method for the calculation of the electronic thermal conductivity was found to be applicable to all types of binary alloys: nontransition, transition, solid solution, and mechanical mixture, whereas the method for the calculation of the lattice thermal conductivity was found to be applicable only to disordered solid-solution alloys; at present the lattice thermal conductivity of alloys in the mechanical-mixture region can be obtained only from experimental data.

For all but two of the binary alloy systems the recommended thermal conductivity values are given for 25 alloy compositions, which greatly facilitates interpolation for alloys with intermediate compositions. Furthermore, since the thermal conductivity of a binary alloy in many cases can be used as a first approximation to the thermal conductivity of a multiple alloy with the same major constituent elements and the same "effective" composition, the recommended thermal conductivity values for the binary alloy systems reported herein can lead the way for the study of the thermal conductivity of multiple alloys.

In the course of this study, a number of areas where further theoretical and experimental research is needed are identified. These areas of further research are recommended and listed below:

(1) Experimental and theoretical work on band structure effects in binary alloys of transition elements and noble elements - in particular measurements on Cu + Pd and Pd + Cu alloys to determine the validity of large Lorenz ratios reported for this system.

(2) Development of quantitative theory of impurity enhancement of phonon-electron interactions at low temperatures.

(3) Measurements of alloy thermal conductivity down to liquid ^3He temperatures to determine the extent to which residual dislocations cause the cusp-like behavior of the composition dependence of the low temperature lattice thermal conductivity.

(4) Development of a theory of low-temperature lattice conduction in transition elements and high-residual-resistivity alloys.

(5) Experimental and theoretical efforts on the lattice thermal conductivity outside the region of solid solubility.

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